Drone Mission Simulations summary

C. Symeonidis, N. Nikolaidis, Y. Basioukas, I. Pitas,
Aristotle University of Thessaloniki, Greece
A. Zhang, S. Boyle, D. Bull (University of Bristol, UK),
C. Le Barz (Thales Services, France)
pitas@csd.auth.gr
www.aiia.csd.auth.gr
Version 4.0

Artificial Intelligence & Information Analysis Lab

Introduction

Simulation is an imitation of the operation of a real-world process or system.

- The corresponding software application, often combined with appropriate hardware is called ***simulator***.
  - Flight simulators.
  - Driving simulators.
  - Medical, e.g., laparoscopic surgery simulators.
  - Disaster management simulators.
  - Robotics simulators.
  - Military, e.g., combat simulators.

UAV simulators

- Simulators are broadly used in UAV tasks for:
  - Having fun (game simulators).
  - Learning to fly and acquire a variety of flight skills under various situations.
  - Developing UAV systems:
    - Testing components functionalities and interoperation before proceeding to the actual implementation.
    - Reducing the risk for drone or third party damage.
  - Refining drone photography or cinematography skills.

UAV simulators

- Gathering data to train / test algorithms for autonomous UAV operation:
  - Data: videos, depth images, UAV state (position, orientation, speed), camera state (orientation, intrinsic parameters).
  - Algorithms: target tracking, crowd detection, UAV control, etc.
- Mission planning and result previewing for, e.g., drone cinematography.
- Evaluating the perceptual quality of drone videos and deciding on the range of acceptable parameters for a certain cinematography mission.

Drone mission simulations

- **Flight / UAV simulators for flight training**
- Simulators for CVML training data generation:
  - AirSim, Sim4CV.
- Drone cinematography simulations.
- Simulators for developing UAV systems:
  - Gazebo.

Simulators for flight training

Real Drone Simulator

- Two types of environments: ‘virtual reality’ (realistic, computer-generated) and real-world (based on Google Earth).
- Drone control via Remote Control (RC), gamepad, keyboard-mouse, etc.
- It contains licensed racing drones.
- Cost: Free.

Simulators for flight training

RealFlight 8 Flight Simulator

- One of the most detailed and powerful simulators on the market.
- Numerous drone/helicopter/plane models and flight environments
- It focuses on enhancing camera and maneuvering skills.
- Allows practicing in various conditions (day, night, different wind speeds) and training scenarios.
- Compatible with Virtual Reality headsets.
- Drone control via RC
- Commercial.

Drone mission simulations

- Flight / UAV simulators for flight training
- **Simulators for CVML training data generation:**
  - **AirSim, Sim4CV.**
- Drone cinematography simulations.
- Simulators for developing UAV systems:
  - Gazebo.

AirSim

- Simulator for drones & cars built upon Unreal Engine 4 (UE4) by Microsoft.
- Built as a platform for AI research to experiment with deep learning, computer vision and reinforcement learning algorithms for autonomous vehicles.
- Open-source, cross platform https://github.com/Microsoft/AirSim
- Supports hardware-in-the-loop with popular flight controllers (PX4) for physically realistic simulations.
- Developed as an UE4 plugin that can be dropped into any Unreal environment.

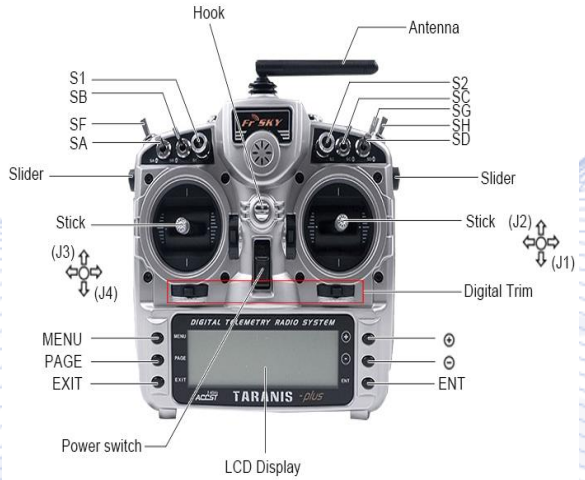
What can you do with AirSim?

- Generate close to real world training data.
- Develop autonomous algorithms.
- Test algorithms.
- Mission planning.
- Learning to fly and acquire skills under various conditions.
- Having fun.

Remote Control

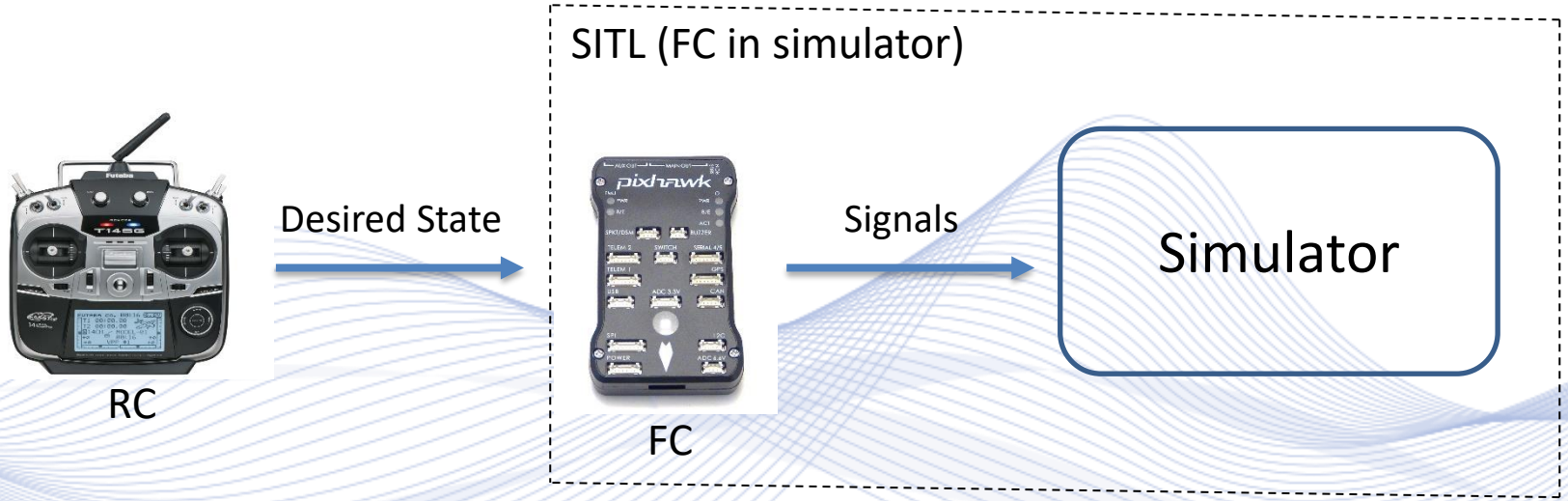
AirSim supports a number of Remote Controls:

FrSky Taranis X9D Plus, Futaba 14SG, DJI Controller, Xbox 360, Gamepad etc



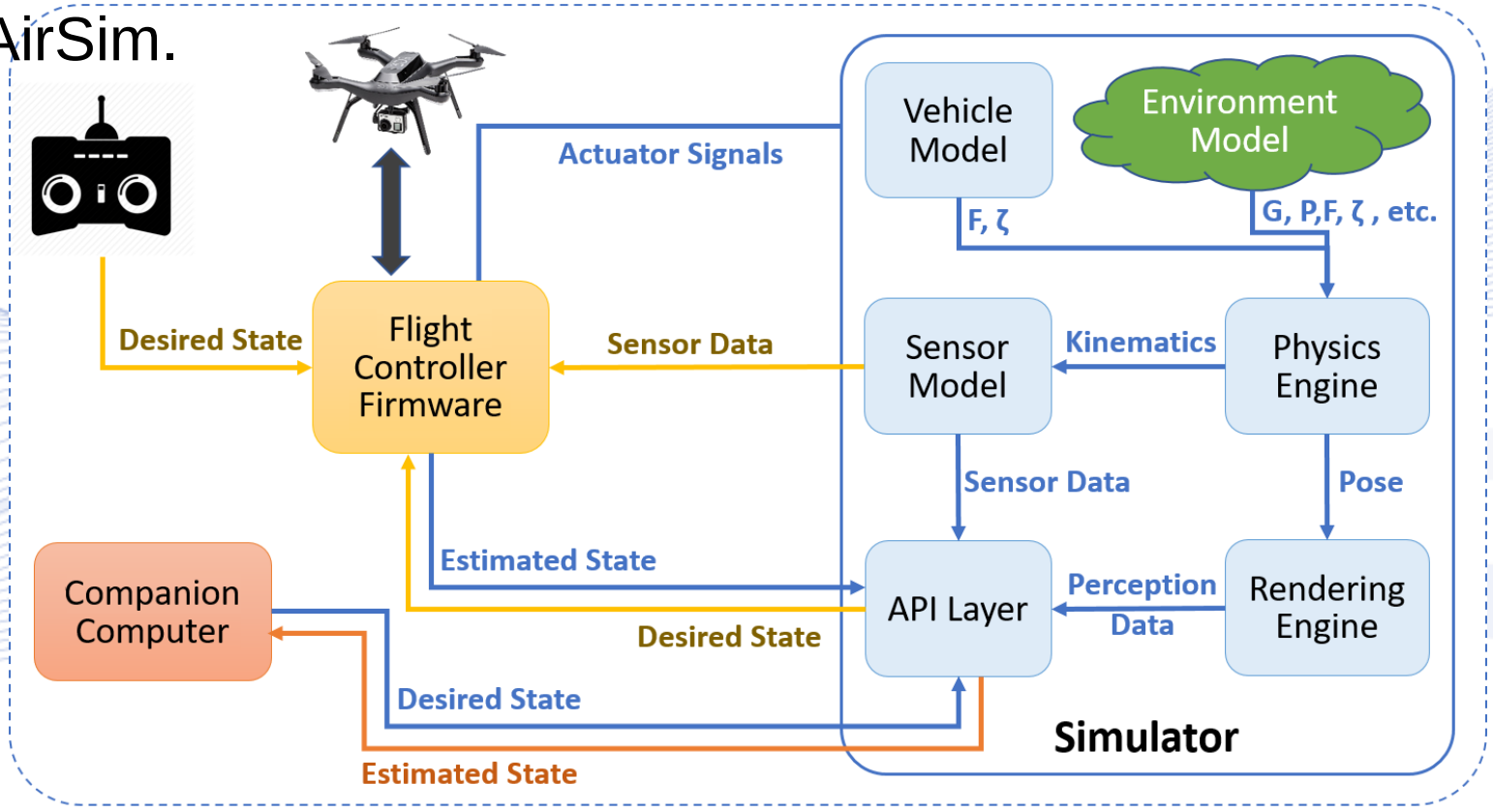
HITL/SITL with Pixhawk

Pixhawk PX4 is an open source very popular flight controller with support for wide variety of boards and sensors as well as built-in capability for higher level tasks such as mission planning.



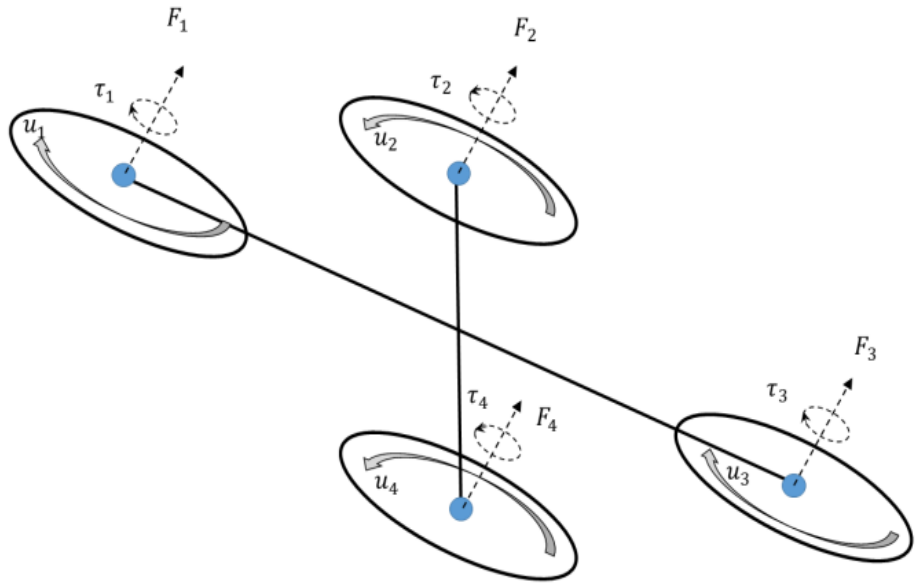
AirSim Architecture

Flight Controller: Direct the RPM of each motor in response to input.
Vehicle Model: Computes forces and torques from the propellers.
Environment Model: Gravitational Acceleration, Air pressure, Density, Magnetic field.
Physics Engine: Compute next kinematic state.
Sensor Model: Sensors of AirSim.
API Layer: C++/Python programming and an independent library.



Vehicle Model

- A vehicle is defined as a collection of K ***vertices*** $\{\boldsymbol{r_1}, .., \boldsymbol{r_k}\}$ and normals $\{\boldsymbol{n_1}, .., \boldsymbol{n_k}\}$.
  - A quadrotor model can be represented by just 4 vertices.
- The vehicle model computes ***forces*** and ***torques*** generated by the propellers, given the ***control motor signals*** provided by the flight controller.
- The vehicle model includes also a number of parameters:
  - mass, inertia, coefficients for linear and angular drag etc.
- These parameters are used by physics engine to compute rigid body dynamics.



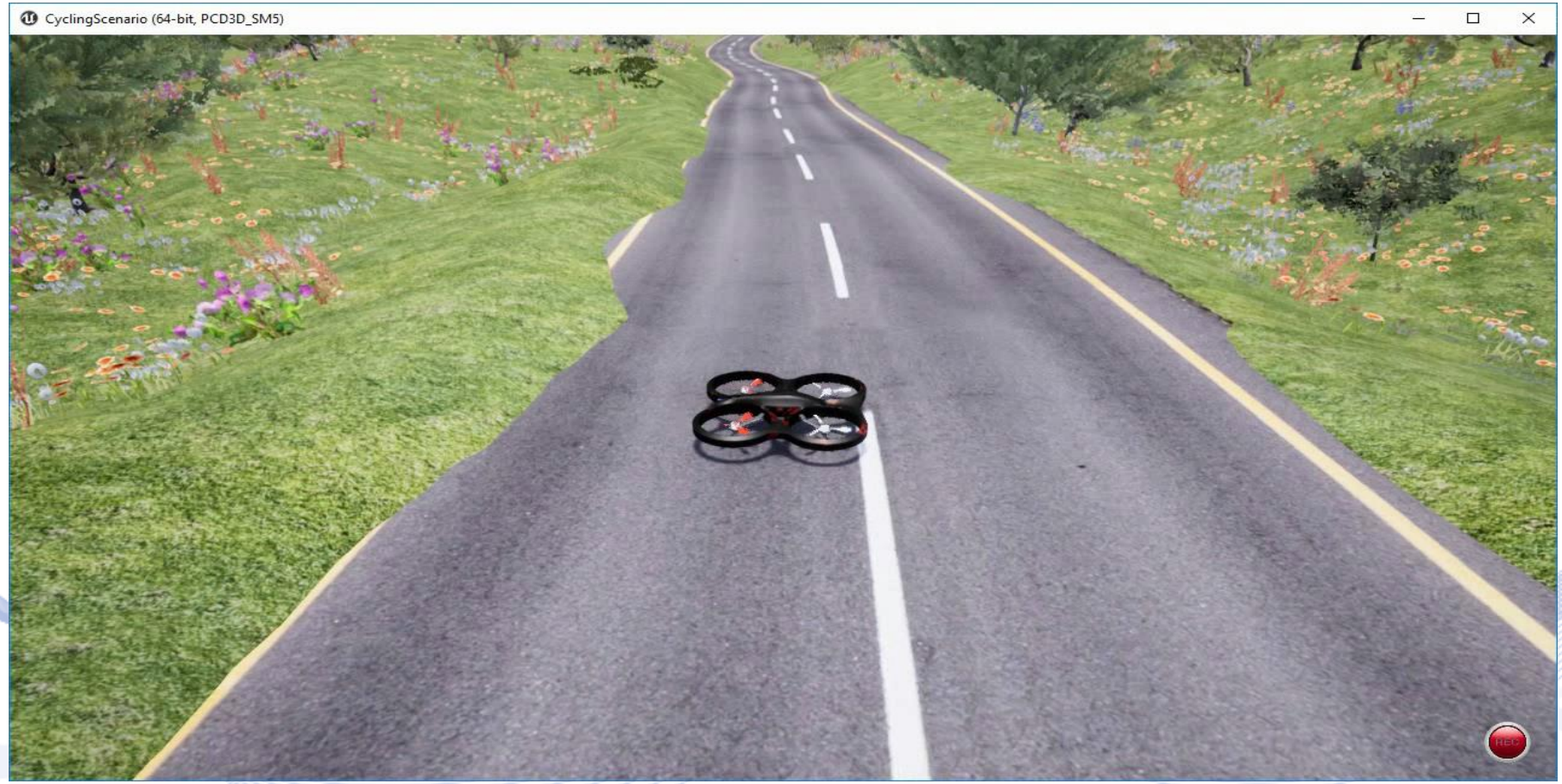
Vehicle model for the quadrotor. The four blue vertices experience the controls $u_1, ..u_4$, which in turn results in the forces $\mathbf{F}_1, .., \mathbf{F}_4$ and the torques $\tau_1, .., \tau_4$.

$$\mathbf{F}_i = C_T \rho \omega_{max}^2 D^4 u_i \text{ and } \tau_i = \frac{1}{2\pi} C_{pow} \rho \omega_{max}^2 D^5 u_i.$$

Programmatic Control

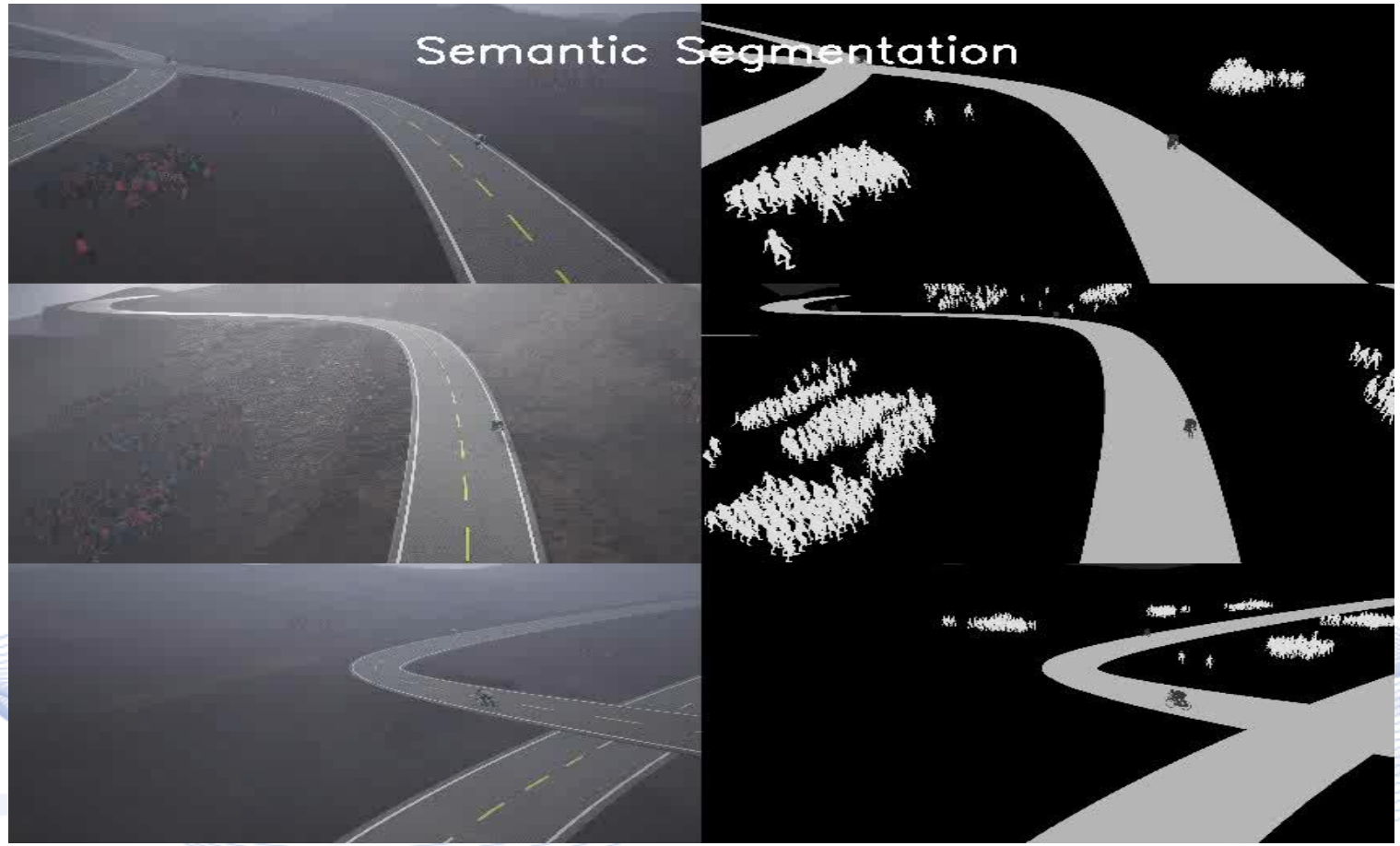
- AirSim exposes APIs to achieve ***programmatic interaction*** with the vehicles.
- APIs can be used to control the vehicle and get:
  - synchronized images from multiple cameras.
  - ground truth info, including: depth, disparity, surface normals, object segmentation.
  - drone state (position, orientation, velocity, etc.).

DNN Training Data Generation



DNN Training Data Generation

DNN Training Data Generation

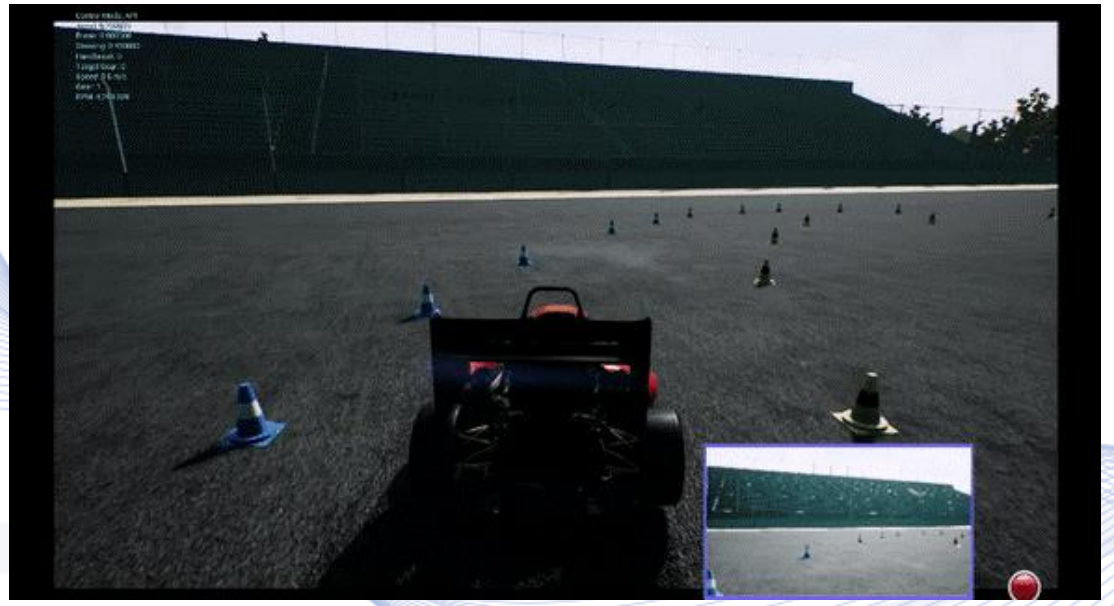


AirSim Drone Racing

AirSim Drone Racing Lab simulator provides a smooth drone trajectory planner and drone race logic:

- High level smooth trajectory planner.
- Trajectory tracking controller.
- Drone racetrack with gates.
- Drone race logic.

Formula Student Autonomous Driving



Sim4CV

Sim4CV (https://sim4cv.org/) is a photo-realistic open-source training and evaluation simulator, built on top of the Unreal Engine.

- The simulator integrates full featured physics-based drones, cars and animated human actors in diverse 3D environments.
- It can reconfigure synthetic worlds on the fly using an automatic world generation tool so as to allow easy generation of large quantities of synthetic data.

Drone mission simulations

- Flight / UAV simulators for flight training
- Simulators for CVML training data generation:
  - AirSim, Sim4CV.
- **Drone cinematography simulations.**
- Simulators for developing UAV systems:
  - Gazebo.

UAV Cinematography Simulations

Based on UAV cinematography experts (pilots, productions teams, editorial teams), the simulations were deemed very useful for rehearsal and scenario planning, especially for live events, when realistic models /rendering of the actual environments exist.

UAV Cinematography Simulations

Drone cinematography simulator to run and test different examples without flying with the real drones. but using the very same software that would run in the real drones.

- In drone-based cinematography, drone and camera parameters and relative motions between camera and target, can have a major influence on viewer experience.
- The aim is to find ***optimal drone parameters*** (drone height, drone speed) for specific shooting scenarios through ***subjective evaluation,*** in terms of viewing experience, on simulation videos.
- The results can help to understand the influence of these parameters in drone cinematography.

Pilot Study - Test Content

O1 Motorcycles

O2 Sports Car

Object Models.

B1 Down Town

B2 Industrial City

Background Environment.

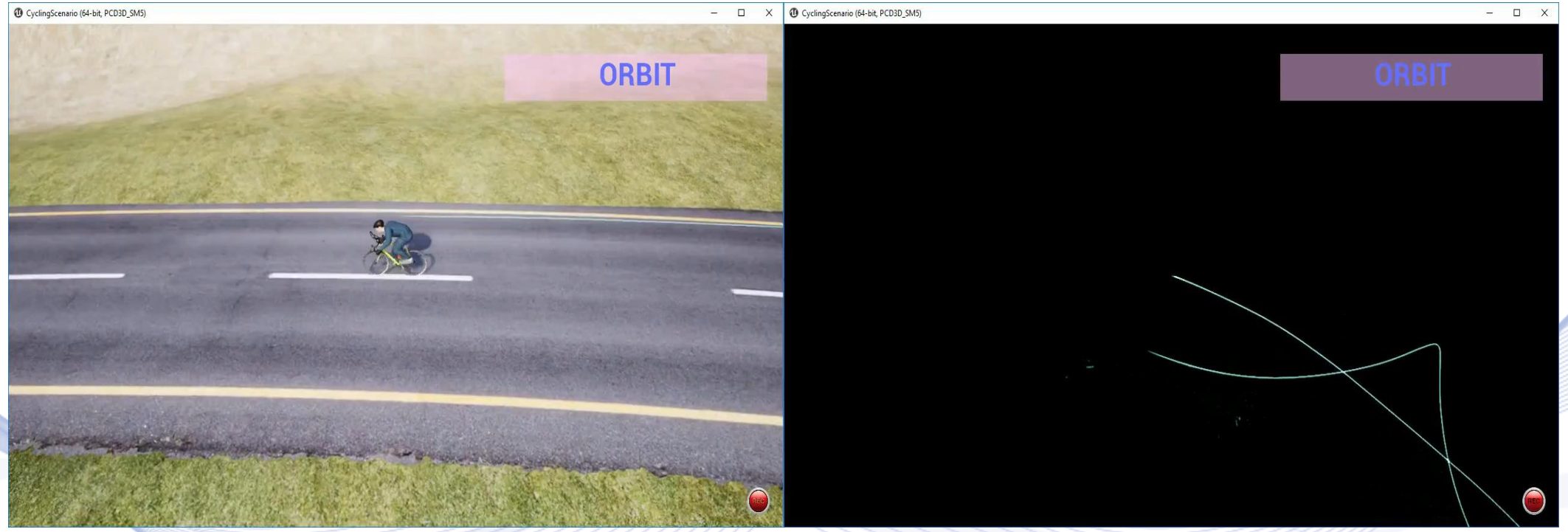
Test Sequence Example: S2

Scenario 2: car racing, drone performing chase with drone height of 1, 2, 6, 10 and 14m.

Test Sequence Example: RacingCar 4

Scenario RacingCar 4, drone overtaking at a flight height of 2, 4, 6, 8 or 10 m.

UAV Shot Type Examples

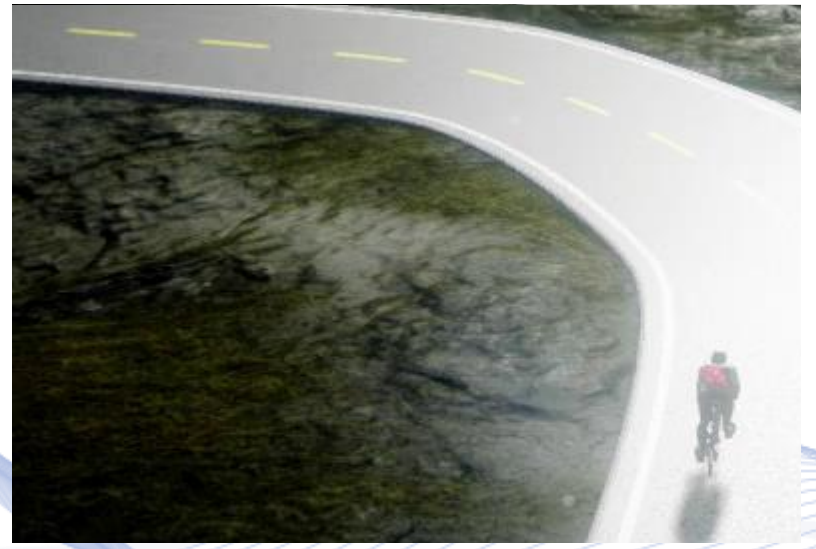


ORBIT shot type around the target.

Drone mission simulations

- Flight / UAV simulators for flight training
- Simulators for CVML training data generation:
  - AirSim, Sim4CV.
- Drone cinematography simulations.
- **Simulators for developing UAV systems**
  - Gazebo.

Vision-based UAV Control



UAV and gimbal control using vision in CHASE shot type.

Vision-based UAV Safe Landing

- Landing sites are stored in a map using a novel algorithm for landing site detection based on DTMs/DSMs.
- Person/Crowd detectors are used in order for the UAV to be aware of their presence.
- During the flight, the detections are projected into the map.

Person detection using YOLO v3.

Drone mission simulations

- Flight / UAV simulators for flight training
- Simulators for CVML training data generation:
  - AirSim, Sim4CV.
- Drone cinematography simulations.
- **Simulators for developing UAV systems**
  - **Gazebo.**

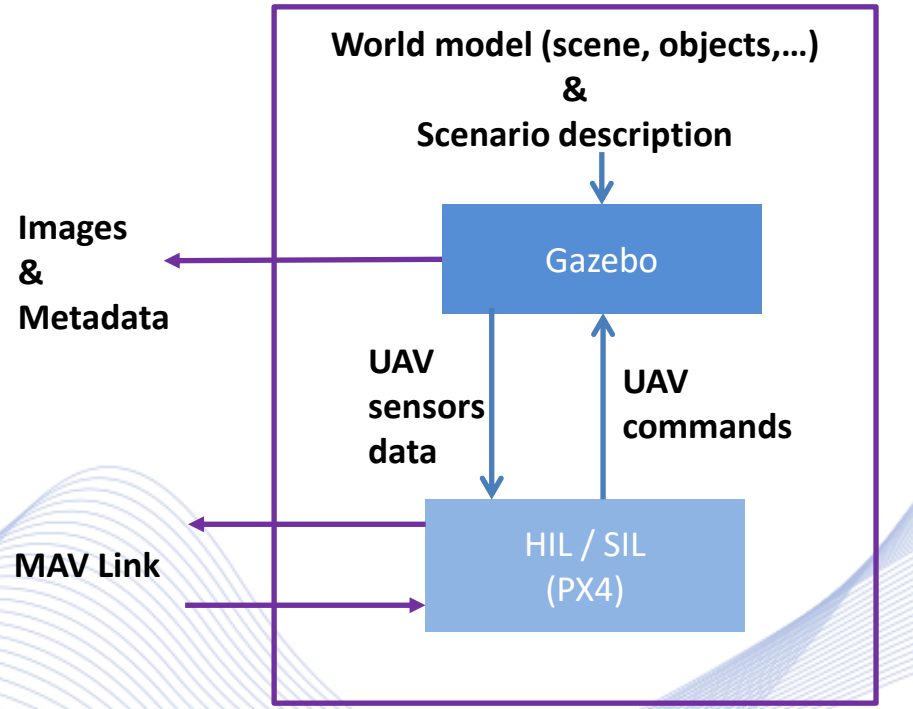
Gazebo Simulator

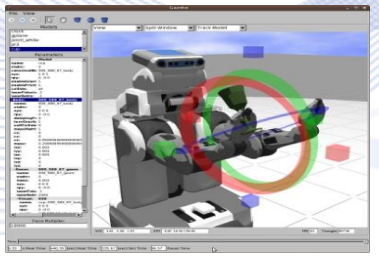
Gazebo is a robotic systems simulator widely used for prototyping, development, troubleshooting and integration of such systems. It provides:

- Seamless integration with Robot Operating System (ROS):
  - Modules of a drone system implemented using ROS can be quickly tested in terms of proper functionality and interoperability before deployment on-drone.
- 3D graphics using OGRE.

Gazebo Simulator

- Gazebo can be connected to a real flight controller/autopilot (HIL) or software autopilot (SITL).
- Many robot models are available. New models can be also created in SDF format.





Gazebo Simulator

CHASE shot type simulation.

Sources

Epic Games, “Unreal engine.” [Online]. Available: https://www.unrealengine.com

Unity Technologies, “Unity.” [Online]. Available: https://unity3d.com/

Epic Games, “Unreal Engine 4 Documentation.” [Online]. Available: https://docs.unrealengine.com/latest/INT/

Gazebo Simulator, “Gazebo” [Online]. Available: http://gazebosim.org/

AirSim Simulator, “AirSim” [Online]. Available: https://github.com/microsoft/AirSim

AirSim Drone Racing Lab: https://github.com/microsoft/AirSim-Drone-Racing-Lab

Technion FS: https://github.com/Microsoft/AirSim/wiki/technion

Bibliography

[KOE2004] N. Koenig, A. Howard, “Design and use paradigms for Gazebo, an open-source multi-robot simulator.”, IROS, 2004

[QIU2016] W. Qiu, A. Yuille, “UnrealCV: Connecting computer vision to Unreal Engine.”, arXiv:1609.01326, 2016.

[SHA2017] S. Shah, D. Dey, C. Lovett, A. Kapoor, “AirSim: High-fidelity visual and physical simulation for autonomous vehicles.”, arXiv:1705.05065, 2017.

[MUE2017] M. Mueller, V. Casser, J. Lahoud, N. Smith, B. Ghanem, “Sim4CV: A photo-realistic simulator for computer vision applications.”, arXiv:1708.05869, 2017.

[BOY2019] S. Boyle, F. Zhang, D. R. Bull, "A Subjective Study of Viewing Experience for Drone Videos using simulated content.“, 2019 IEEE International Conference on Image Processing (ICIP), 2019.

Bibliography

[MUE2016] M. Mueller, N. Smith, B. Ghanem, “A Benchmark and Simulator for UAV Tracking”, European Conference on Computer Vision (ECCV), 2016

[BON2019] R. Bonatti, R. Madaan, V. Vineet, S. Scherer, A. Kapoor, . Learning Controls Using Cross-Modal Representations: Bridging Simulation and Reality for Drone Racing, 2019.

[MUE2018] M. Mueller, Vincent Casser, Jean Lahoud, Bernard Ghanem, "Sim4CV: A photo-realistic simulator for computer vision applications", International Journal on Computer Vision (IJCV) September 2018.

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