Intelligent unmanned cluster system development and practice Full-stack development case based on RflySim toolchain

Lecture 10 Cluster control algorithm development

飞思实验室

outline

1. Experimental platform configuration
2. Introduction to key interfaces
3. Basic experimental cases
   (free version)
4. Advanced interface experiment
   (personal version)
5. Advanced case experiments
   (collection version)
6. Extended case
   (full version)
7. Summary

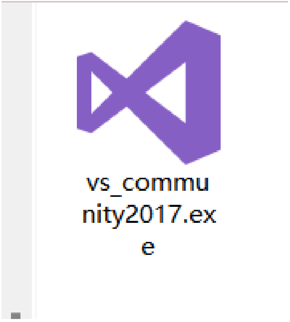
1. Installation method

- **1.1 Components that need to be installed**
- **• Visual Studio 2017 (both trial and full versions need to be installed)**
- **• Configure the C++ compiler for MATLAB (both trial and full versions need to be installed)**
- **• Matlab 2023a* (advanced full version installation)**

The following describes the installation method of Visual Studio 2017 (requires Internet connection): In this platform, the installation package of Visual Studio 2017 has been placed

1. Installation method

- 1.2 Installation method of Visual Studio 2017
- • First, we can open the platform installation location and find the location *:\PX4PSP\RflySimAPIs. Here are some routines in the platform and software installation packages.
- • After that, we can open the content of Chapter 4 and find the basic version of the routine, 4.RflySimModel .BasicExps, where we can find the folder named VS2017Installer, which is the installation package of Visual Studio 2017.

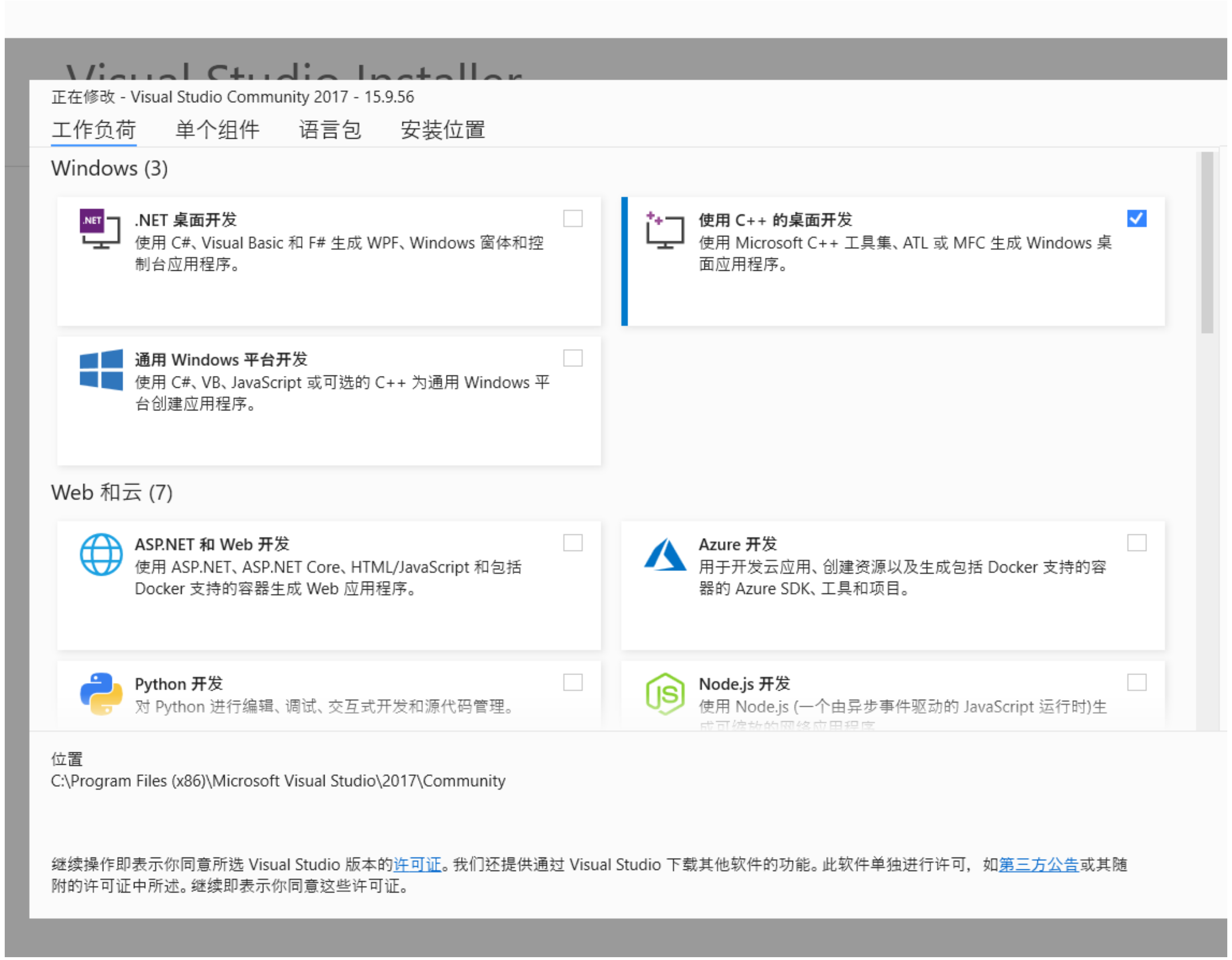


Online installation steps (requires Internet connection) are as follows: Visual Studio Older Downloads - 2019, 2017, 2015, and previous versions (microsoft.com)

1. Installation method

1.2 Installation method of Visual Studio 2017

- Install Visual Studio 2017 (you can also use other versions, as long as MATLAB can recognize it).
- The Visual Studio compiler will be used in many areas of subsequent courses, such as the use of MATLAB S-Function Builder module, Simulink automatically generating C/C++ model code, etc.
- For this course content, you only need to check "Desktop Development in C++" in the picture on the right.



1. Installation method

- 1.2 Installation method of Visual Studio 2017

- Note: Higher versions of MATLAB can also install VS2019, but MATLAB can only recognize Visual Studio versions lower than its own, so MATLAB 2017b cannot recognize VS 2019.

- Note: Please do not change the default installation directory of VS (for example, install to drive D), otherwise MATLAB will not be recognized.

- Cannot use Mingw compiler, requires VS

1. Installation method

- ## 1.3 Configure the C++ compiler for MATLAB

• Enter the command “mex - setup” in the MATLAB command line window

• Generally speaking, the VS 2017 compiler will be automatically recognized and installed. As shown in the picture on the right, "MEX is configured to use 'Microsoft Visual C++ 2017' for compilation", indicating that the installation is correct.

• If there are other compilers, you can also switch to other compilers such as VS 2013/2015 on this page

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1. Installation method

- **1.4 Installation method of Matlab 2023a**
- **MATLAB installation package download path:**
- **https://ww2.mathworks.cn/products/matlab.html**

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outline

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2. Introduction to key interfaces

- **2.0 Overview of Basic Experiments**

Including basic function interface "RflySimAPIs/10.RflySimSwarm

For details, see API_en.pdf and Readme_en.pdf

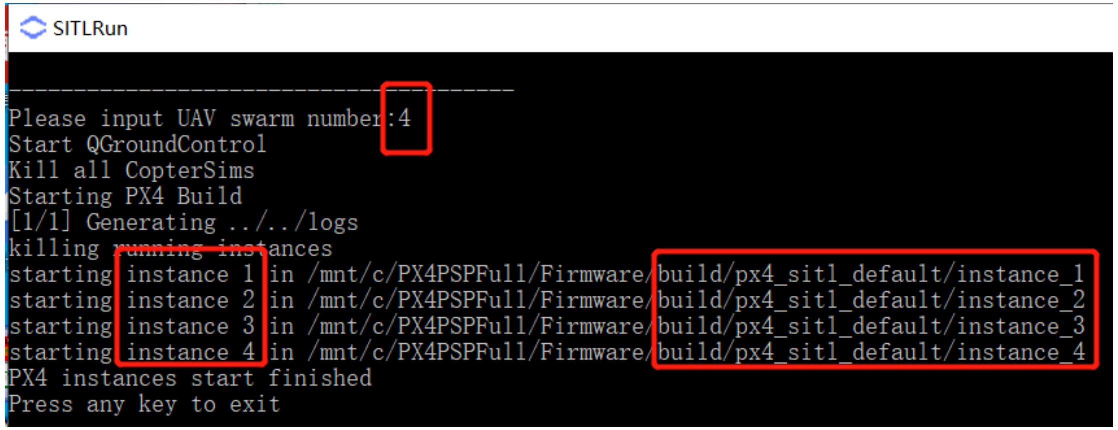
1.SwarmLogGet	2023/12/13 15:04	文件夹
2.MatRflySwarmAPIPack	2023/12/13 15:04	文件夹
3.EXEFileGener	2023/12/21 11:19	文件夹
4.RebootPixViaUDP	2023/12/13 15:04	文件夹
5.GetTerrainAPI	2023/12/13 15:04	文件夹
6.DataAnalysis_Mat	2023/12/13 15:04	文件夹
7.DataAnalysis_Py	2023/12/13 15:04	文件夹
8.MAVLinkFull4Swarm	2023/12/13 15:04	文件夹

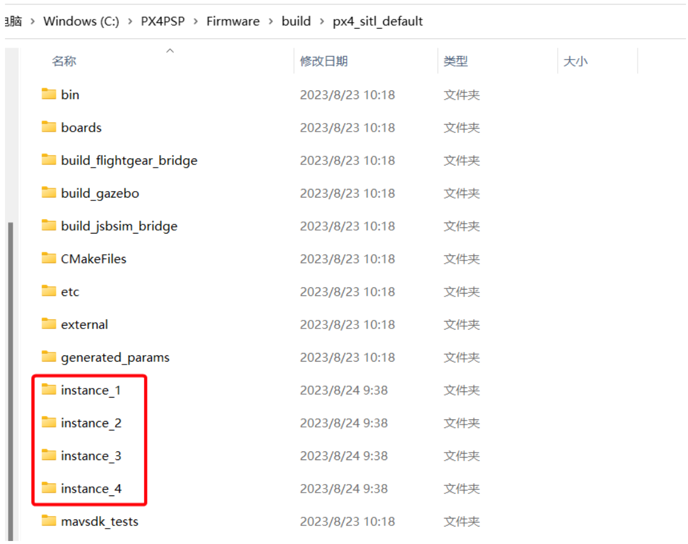
e1_RflyUdpSwarmExp	2023/12/13 15:04	文件夹
e2_NoPX4SITL4Swarm	2023/12/13 15:04	文件夹
e3_LightShowSwarm	2023/12/13 15:04	文件夹
e4_FixWingGMSwarm	2023/12/13 15:04	文件夹

2. Introduction to key interfaces

- 2.1 SIL simulation log acquisition experiment

- When performing SIL simulation, RflySim will automatically record the Log log of each aircraft and generate a .ulg format file.
- For detailed operations and experimental results, see 0.ApiExps\1.SwarmLogGet\Readme_En.pdf

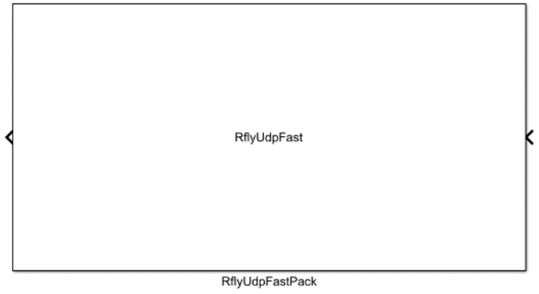


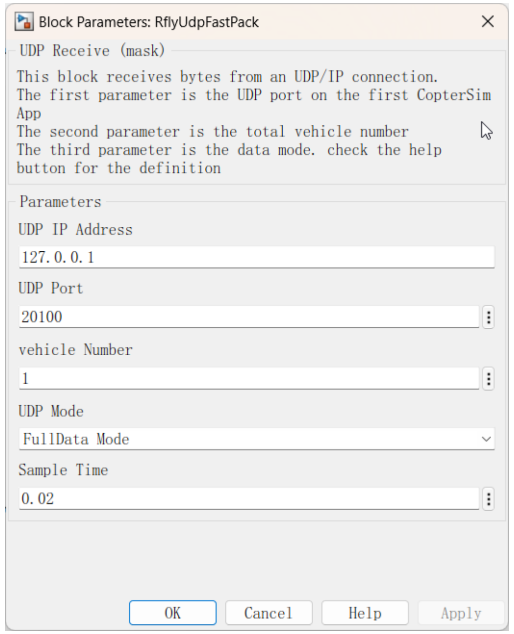


2. Introduction to key interfaces

- **2.2 MATLAB cluster interface model packaging experiment**
- **The MATLAB cluster interface module of the RflySim platform adopts a mixed form of C++/S-functions. This experiment will explain how to encapsulate the completed C++ file into a Simulink module.**

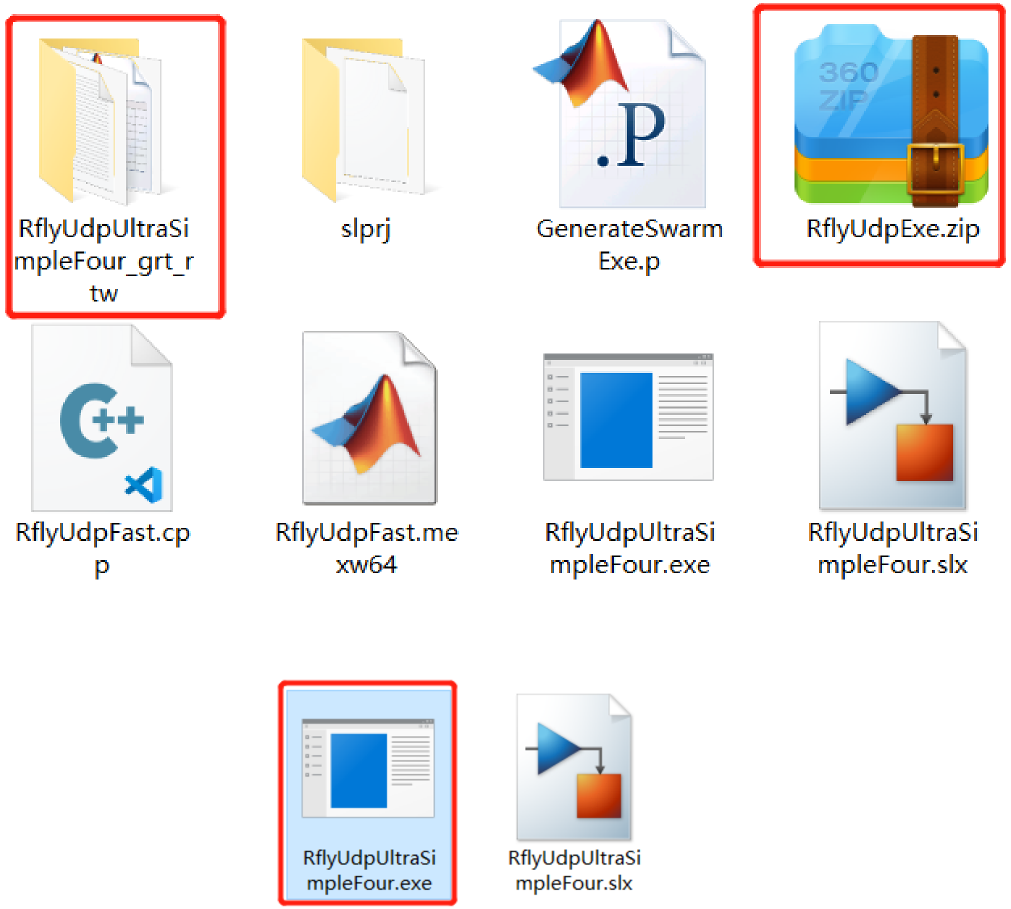
- **For detailed operations and experimental results, see [0.ApiExps\2.MatRflySwarmAPIPack\Readme_En.pdf]**





2. Introduction to key interfaces

- **2.3 .exe file generation experiment**
- **After the Simulink controller is compiled and generated into an exe, the algorithm can be run without MATLAB, and it is a binary executable file itself, which has very high operating efficiency. Even large-scale control algorithms can ensure real-time control.**
- **For detailed operations and experimental results, see** [0.ApiExps\3.EXEFileGener\Readme_En.pdf]



2. Introduction to key interfaces

- **2.4 Flight control hardware remote restart experiment**

- **This experiment uses broadcast mode to restart all HITL simulations in the LAN.**

- **For detailed operations and experimental results, see [0.ApiExps\4.RebootPixViaUDP\Readme_En.pdf]**

2. Introduction to key interfaces

- **2.5 Multi-machine terrain height acquisition interface experiment**
- **The RflySim platform provides a height information acquisition interface, which allows you to automatically configure the initial position of the aircraft given the number and spacing of aircraft, and calculate the terrain height based on the current terrain, just like the bat startup script.**
- **For detailed operations and experimental results, see [0.ApiExps\5.GetTerrainAPI\Readme_En.pdf]**

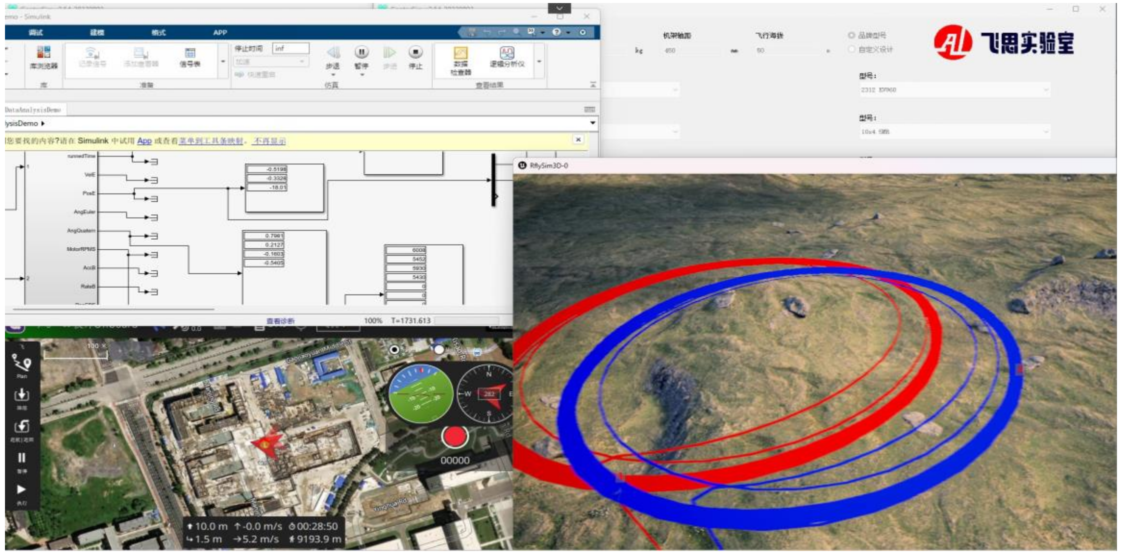
```
>> GenSwarmPos12
Init pos and yaw lists for ***Pos.bat is :
PosXStr=0,0,0,0,2,2,2,2,4,4,4,4
PosYStr=0,2,4,6,0,2,4,6,0,2,4,6
YawStr=0,0,0,0,0,0,0,0,0,0,0,0

Alt list is
Alt=-8.0485,-7.7987,-7.4631,-7.1196,-8.2515,-7.

Init Pos and Yaw list for Python is:
InitPosList=[
    [-8.0485,0,0,0],
    [-7.7987,0,2,0],
    [-7.4631,0,4,0],
    [-7.1196,0,6,0],
    [-8.2515,2,0,0],
    [-7.7519,2,2,0],
    [-7.5333,2,4,0],
    [-7.3226,2,6,0],
    [-8.3685,4,0,0],
    [-8.1188,4,2,0],
    [-7.7831,4,4,0],
    [-7.3772,4,6,0],
]
```

2. Introduction to key interfaces

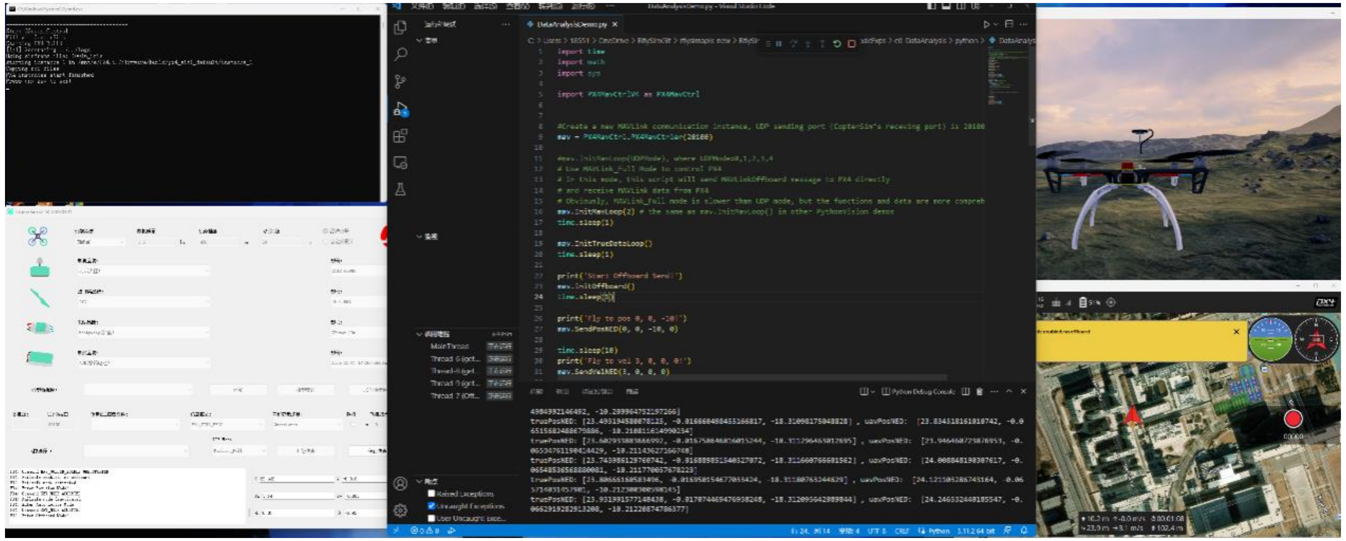
- **2.6 Data analysis experiment based on Simulink**
- **The RflySim platform has rich flight log acquisition and analysis functions. This experiment will be based on Simulink to achieve real-time acquisition and storage analysis of flight logs.**
- **For detailed operations and experimental results, see [0.ApiExps\6.DataAnalysis_Mat\Readme_En.pdf](0.ApiExps\6.DataAnalysis_Mat\Readme_En.pdf)**



```
subplot(2,1,1);
plot(PosE1.Data(:,1),PosE1.Data(:,2))
subplot(2,1,2);
plot(PosE2.Data(:,1),PosE2.Data(:,2))
```

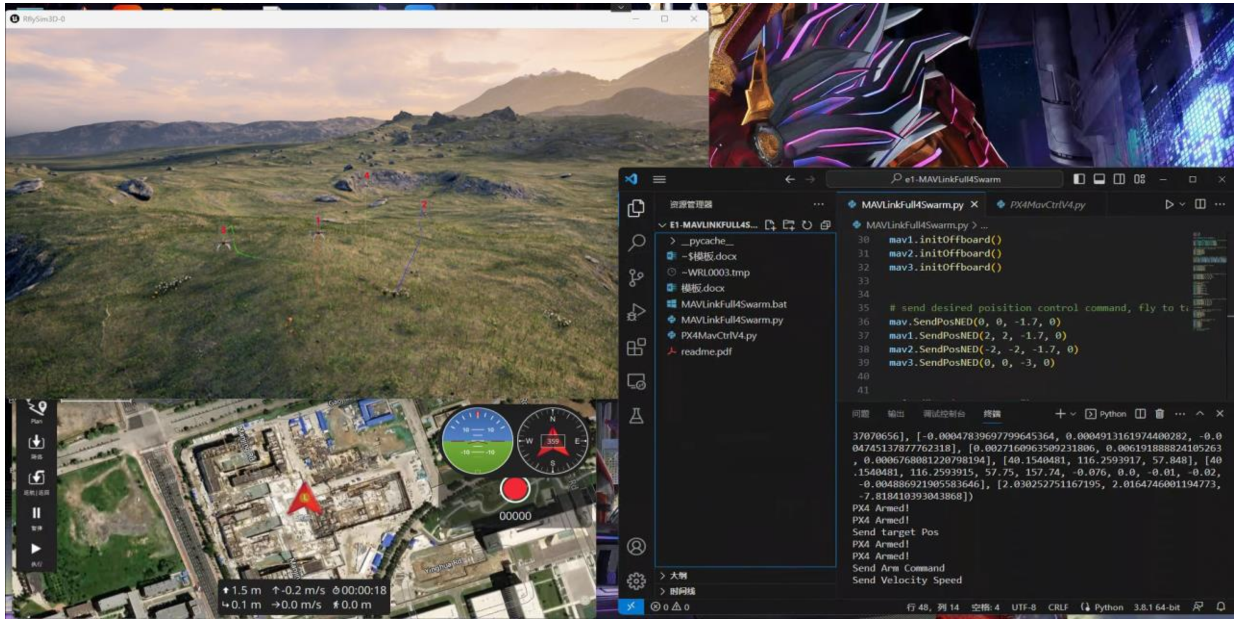
2. Introduction to key interfaces

- **2.7 Data analysis based on Python**
- **The experimental RflySim platform has rich flight log acquisition and analysis functions. This experiment will implement real-time acquisition and storage analysis of flight logs based on Python.**
- **For detailed operations and experimental results, see [0.ApiExps\7.DataAnalysis_Py\Readme_En.pdf]**



2. Introduction to key interfaces

- **2.8 Cluster interface experiment**
- **UAV position control, speed control, and heading control are carried out by using the RflySim platform mavlink communication function interface.**
- **For detailed operations and experimental results, see [0.ApiExps\8.MAVLinkFull4Swarm\Readme_En.pdf]**



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   (full version)
7. Summary

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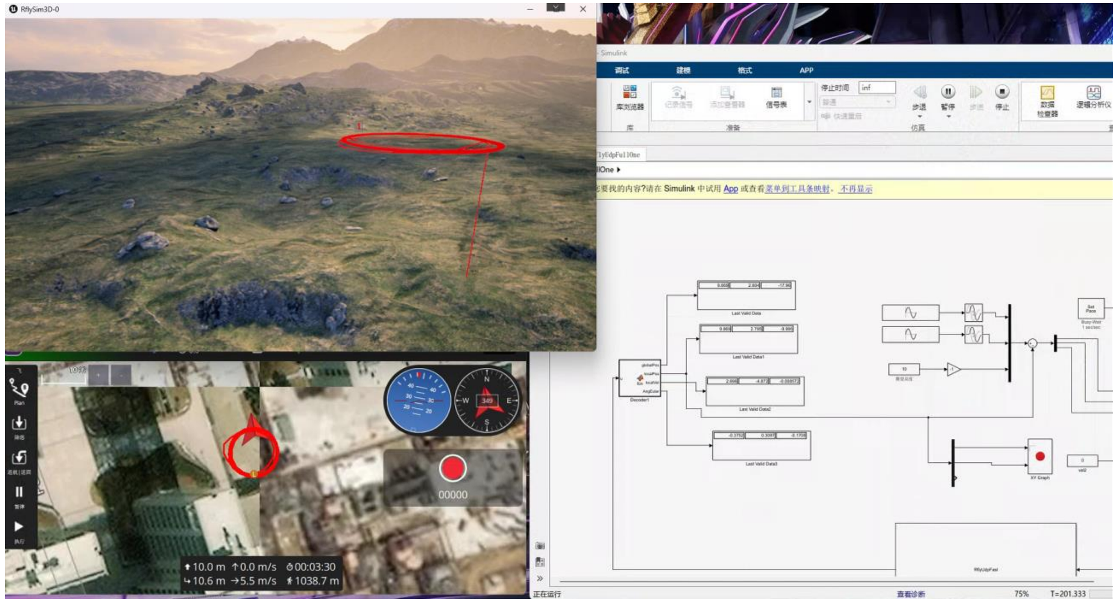
3. Basic experimental cases

- **3.1.1 FullData mode stand-alone experiment of communication interface**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drone is received, and then simulink modeling is performed to control the local position motion of a single drone, and the control instructions are sent to the module, and then simulated.**
- **For detailed operations and experimental results, see 1.BasicExps\e1_RflyUdpSwarmExp\1.RflyUdpFullOne_Mat\Readme_En.pdf**



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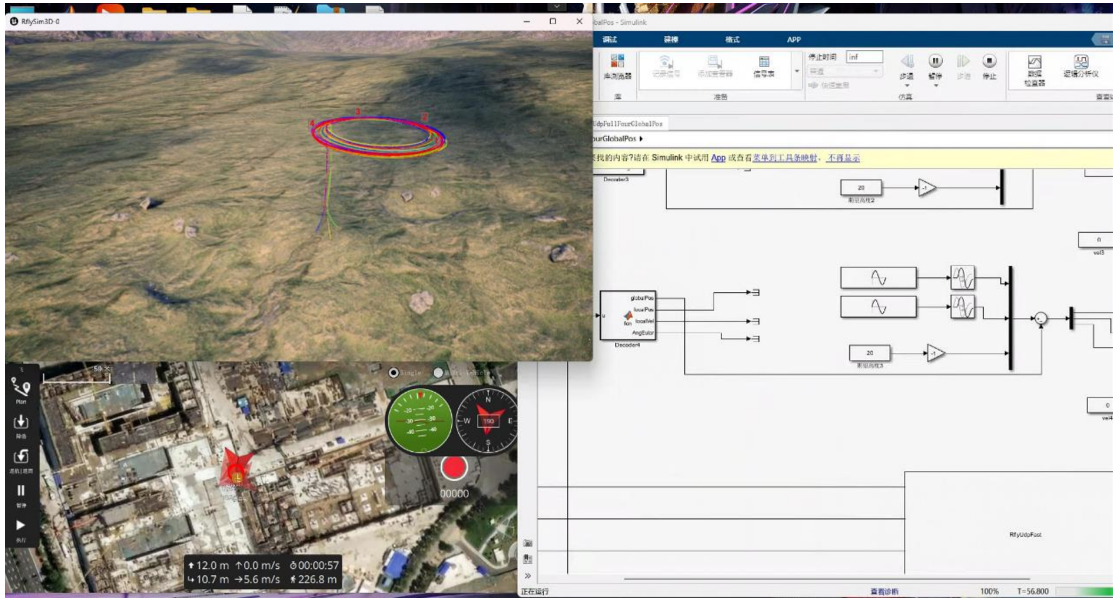
3. Basic experimental cases

- **3.1.2 FullData mode 4-machine simulation experiment of communication interface**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drones is received, and then simulink modeling is performed to control the local position motion of the four drones, and the control instructions are sent to the module, and then simulated.**
- **For detailed operations and experimental results, see 1.BasicExps\e1_RflyUdpSwarmExp\2.RflyUdpFullFour_Mat\Readme_En.pdf**

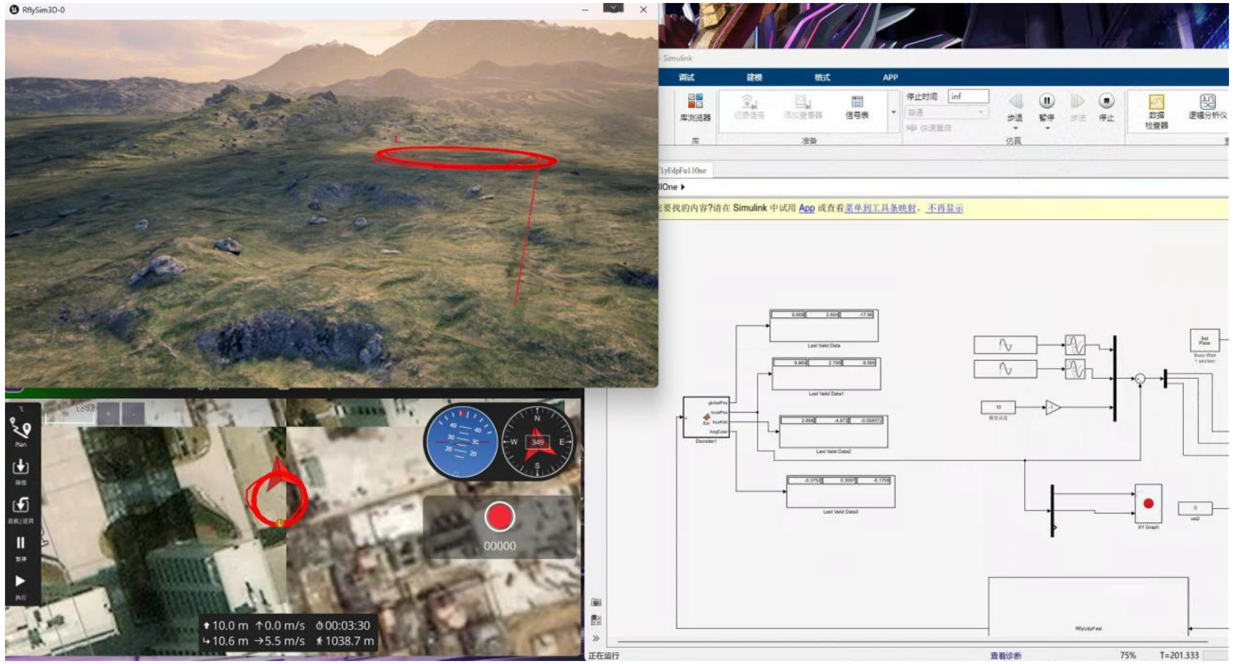
3. Basic experimental cases

- **3.1.3 Communication interface FullData mode global coordinate control 4-machine experiment**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drone is received, and then Simulink modeling is performed to control the global position motion of the drone, and the control instructions are sent to the module, and then the simulation is performed.**
- **For detailed operations and experimental results, see** 1.BasicExps\e1_RflyUdpSwarmExp\3.RflyUdpFullFourGPos_Mat\Readme_En.pdf



3. Basic experimental cases

- **3.1.4 Single-machine circle drawing experiment in SimpleData mode of communication interface**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drone is received, and then simulink modeling is performed to control the local position motion of a single drone, and the control instructions are sent to the module, and then simulated.**
- **For detailed operations and experimental results, see 1.BasicExps\e1_RflyUdpSwarmExp\4.RflyUdpSimpleOne_Mat\Readme_En.pdf**



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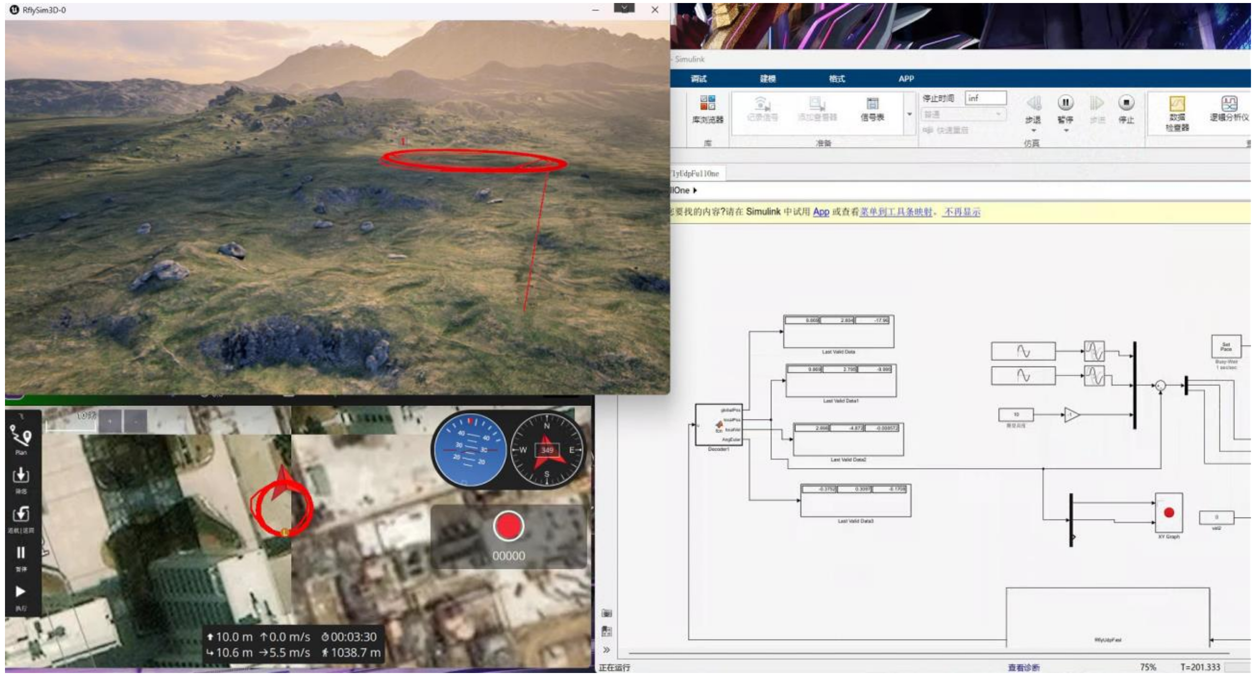
3. Basic experimental cases

- **3.1.5 Single-machine circle drawing experiment in UltraSimple mode of communication interface**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drone is received, and then simulink modeling is performed to control the local position motion of a single drone, and the control instructions are sent to the module, and then simulated.**
- **For detailed operations and experimental results, see 1.BasicExps\e1_RflyUdpSwarmExp\5.RflyUdpUltraSimpleOne_Mat\Readme_En.pdf**



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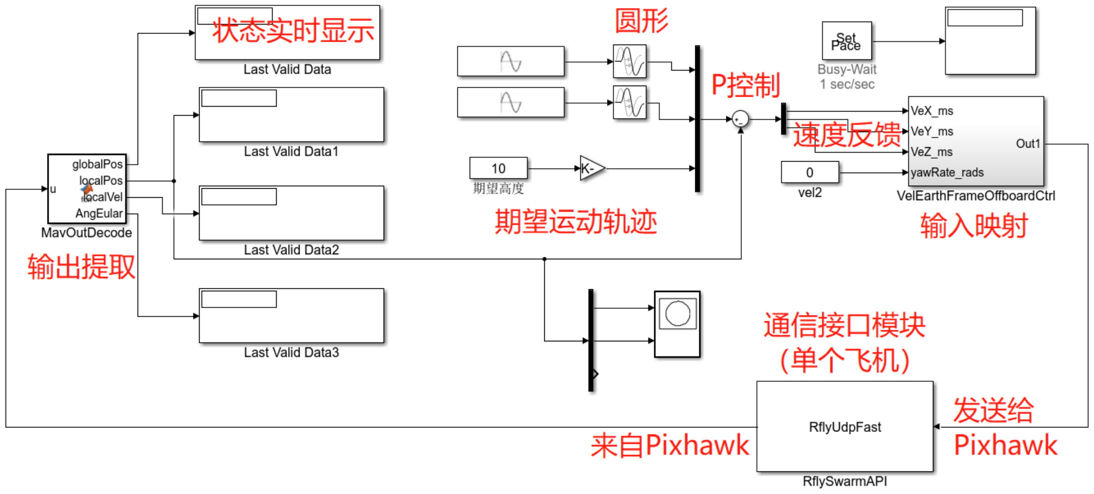
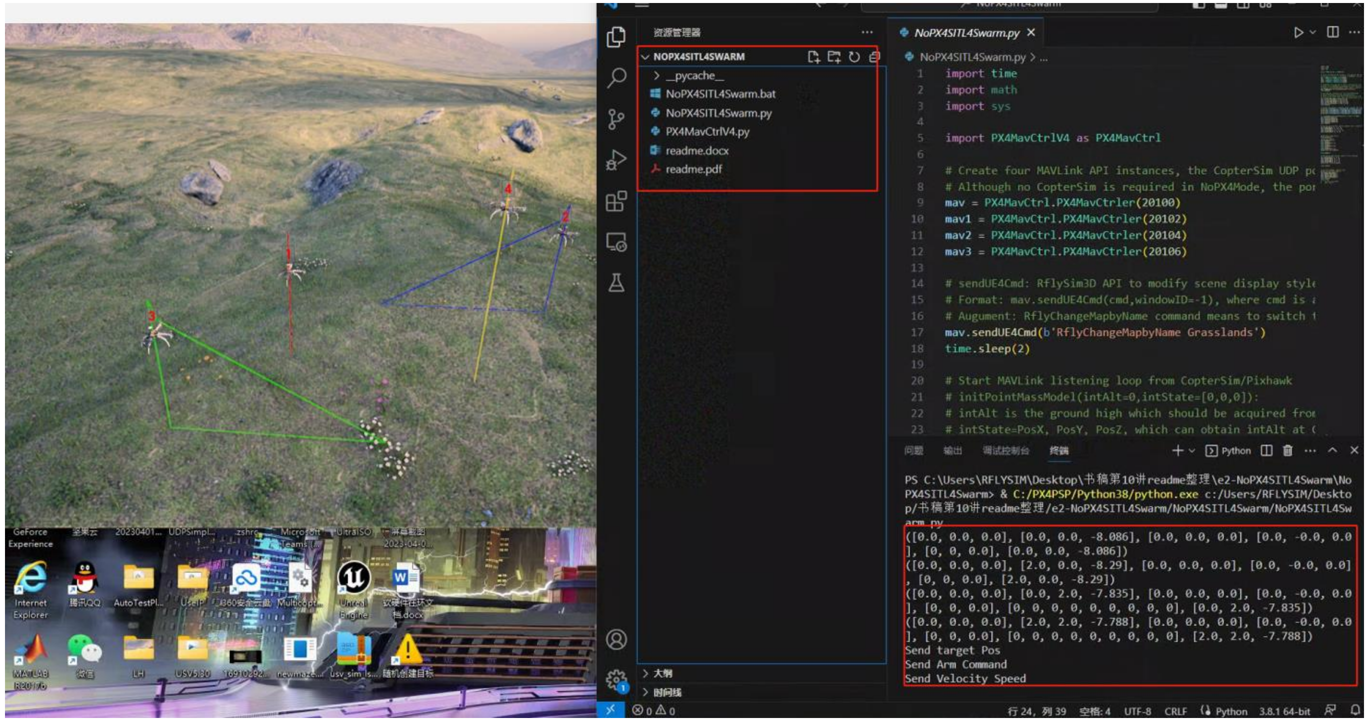
3. Basic experimental cases

- **3.1.6 Four-machine circle drawing experiment in UltraSimple mode of communication interface**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drone is received, and then Simulink modeling is performed to control the local position motion of a single drone, and the control instructions are sent to the module, and then simulated.**
- **For detailed operations and experimental results, see** [1.BasicExps\e1_RflyUdpSwarmExp\6.RflyUdpUltraSimpleFour_Mat\Readme_En.pdf]



3. Basic experimental cases

- **3.2 4-organic point cluster experiment**
- **This platform has developed a particle multi-rotor model under Python. Only two softwares, Python and RflySim3D, can realize hundreds of pilot-level UAV cluster simulations on a single computer.**
- **For detailed operations and experimental results, see [1.BasicExps\e2_NoPX4SITL4Swarm\Readme_En.pdf]**

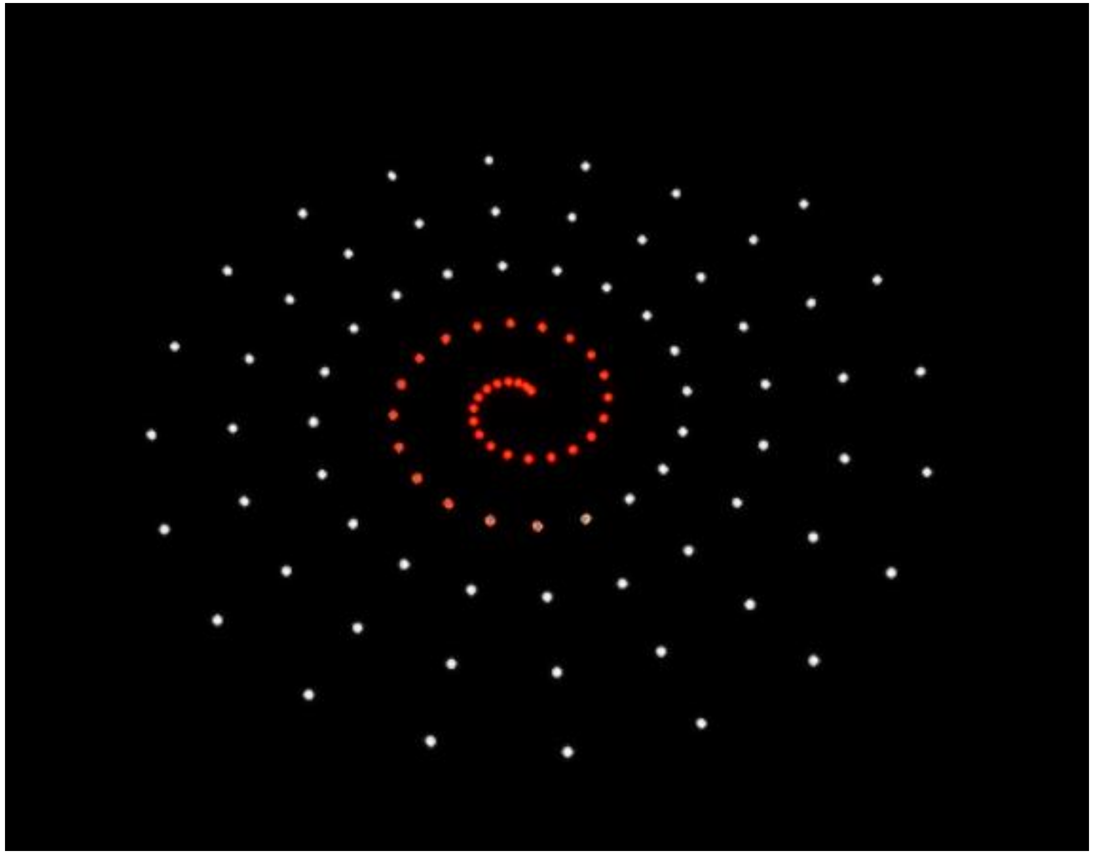


3. Basic experimental cases

- ## 3.3 Cluster track lighting display experiment

- **The lighting change special effects of this routine actually use the same interface (different lighting styles) as the C key in RflySim3D to switch the aircraft style. Through this interface, the simulation of crash animation after impact and other special effects can be realized.**

- **For detailed operations and experimental results, see 1.BasicExps\e3_LightShowSwarm\Readme_En.pdf**

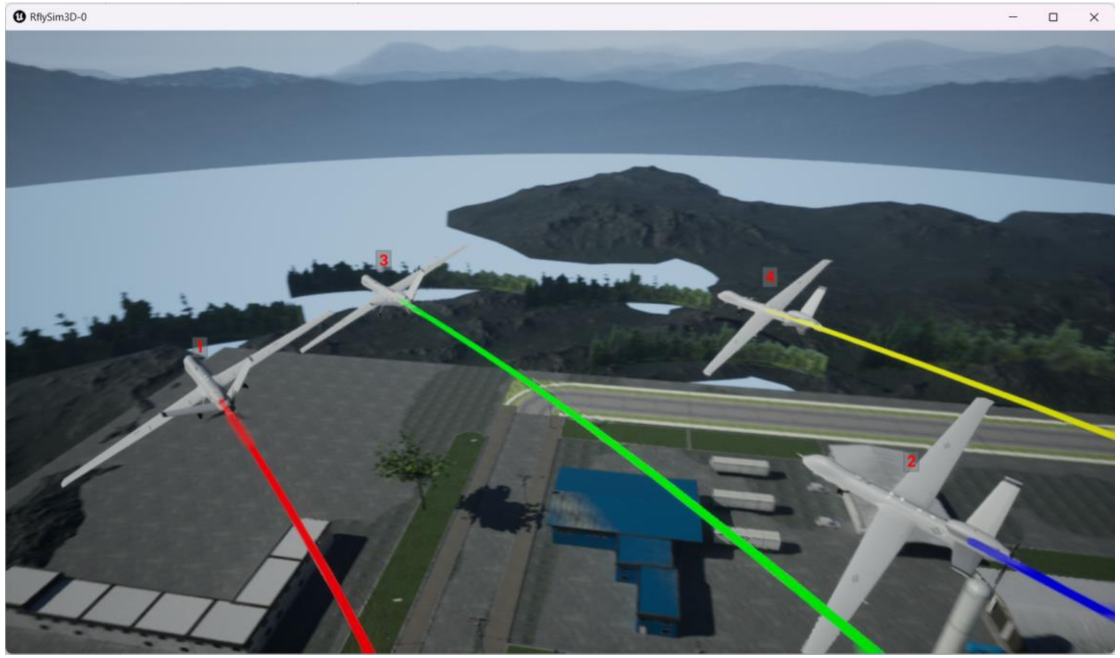


3. Basic experimental cases

- ## 3.4 Fixed wing particle model cluster experiment

- In this experiment, a fixed-wing particle model was built, which can control the fixed-wing to fly on a predetermined trajectory through speed, yaw, height or position commands.

- For detailed operations and experimental results, see 1.BasicExps\e4_FixWingGMSwarm\Readme_En.pdf



3. Basic experimental cases

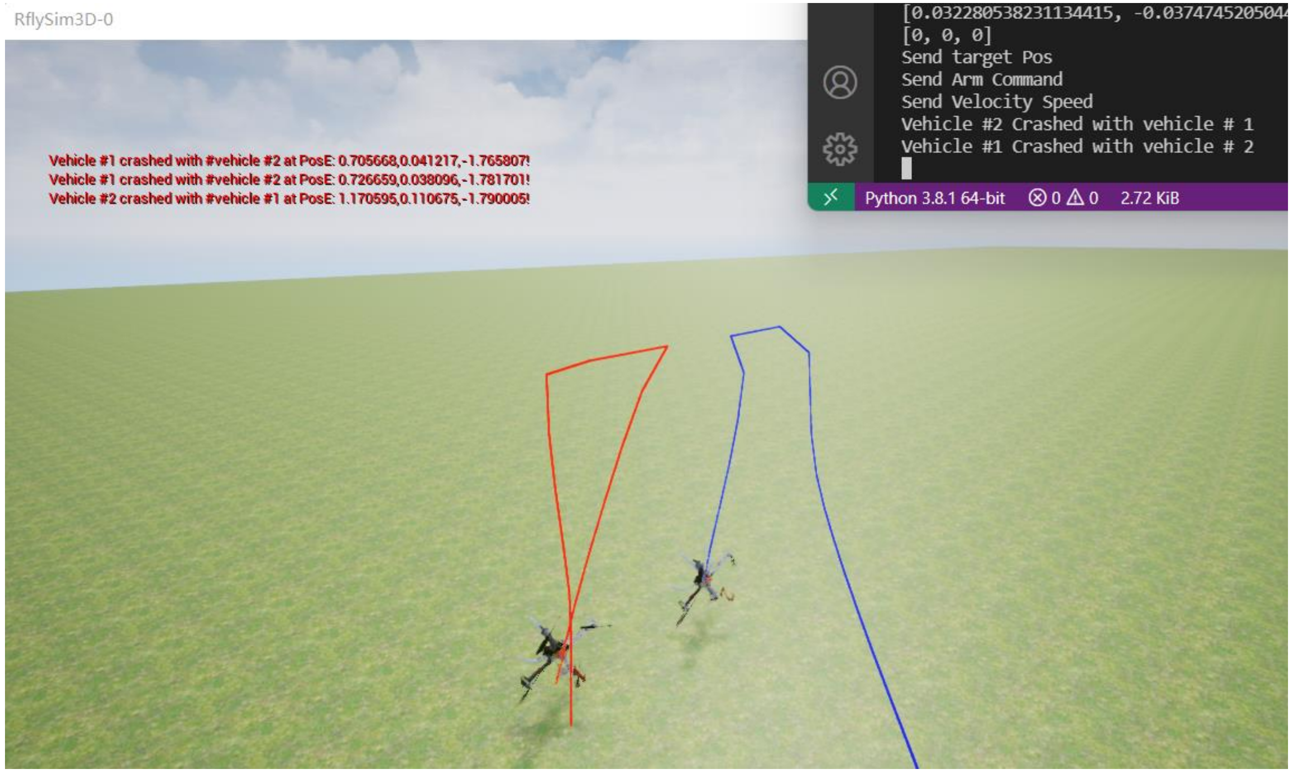
- **3.5.1 RflySim3D collision interface experiment**

- **This experiment demonstrates how to achieve the collision effect of drones in the three-dimensional engine by calling the collision API interface of the RflySim platform.**

- **For detailed operations and experimental results, see [1.BasicExps\e5_CollisionExpAPI\1.CrashMonitorAPI\Readme_En.pdf]**

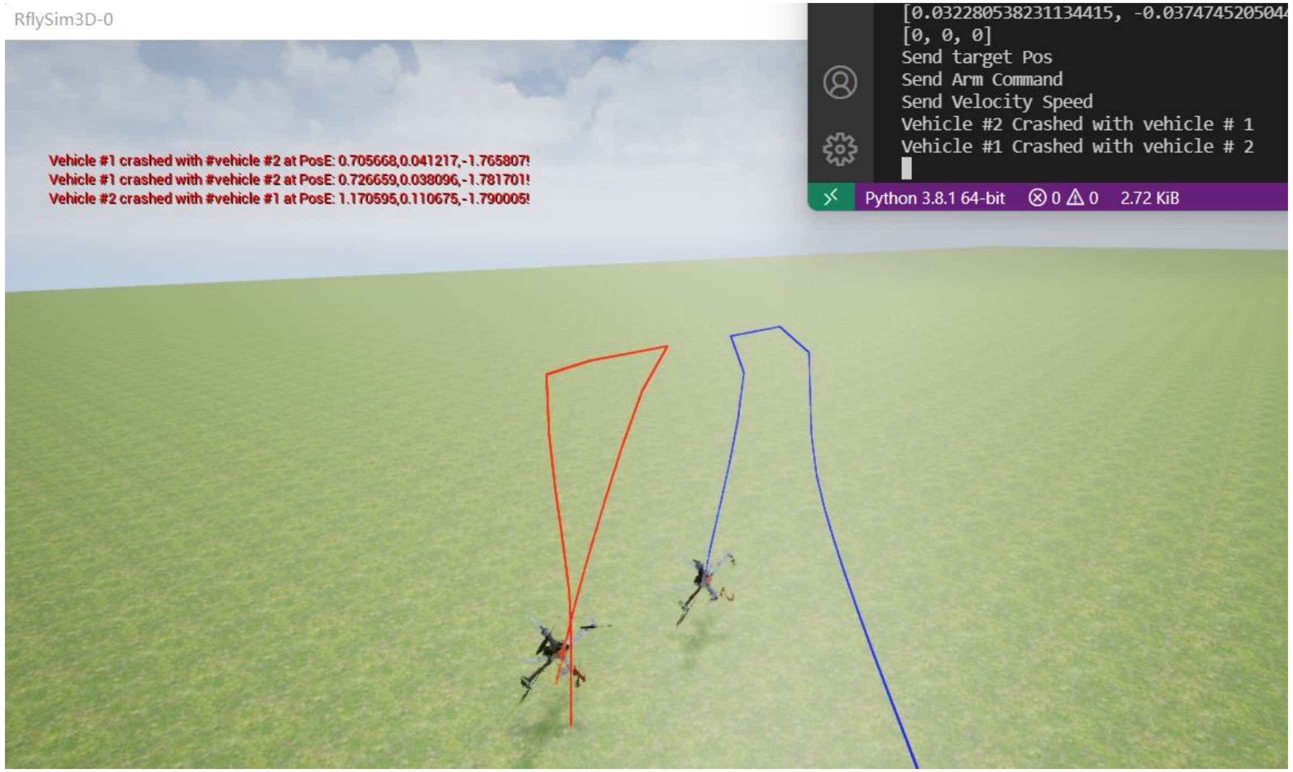
3. Basic experimental cases

- **3.5.2 MAVLink mode 2 machine collision experiment**
- **The three-dimensional scene simulation software RflySim3D of the RflySim platform is developed based on UE. During the development process, it has a collision engine mode. This example shows the detailed process of two aircraft from takeoff to collision.**
- **For detailed operations and experimental results, see 1.BasicExps\e5_CollisionExpAPI\2.CollMAVLinkAPI_Py\Readme_En.pdf**



3. Basic experimental cases

- **3.5.3 UDP mode 2 machine collision experiment**
- **The three-dimensional scene simulation software RflySim3D of the RflySim platform is developed based on UE. During the development process, it has a collision engine mode. This example shows the detailed process of two aircraft from takeoff to collision.**
- **For detailed operations and experimental results, see [1.BasicExps\e5_CollisionExpAPI\3.CollUDPModeAPI_Py\Readme_En.pdf]**



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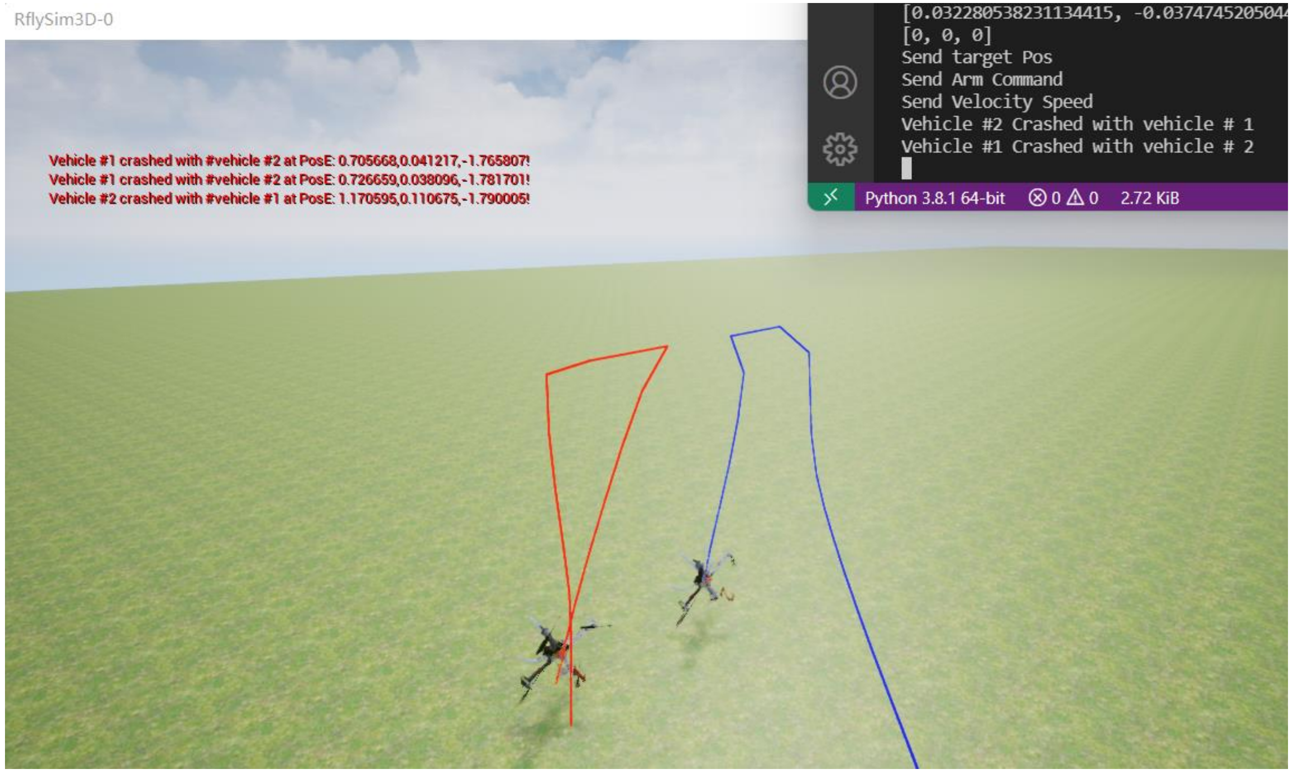
3. Basic experimental cases

- **3.5.4 UDP mode 2 machine collision (Simulink) experiment**
- **The three-dimensional scene simulation software RflySim3D of the RflySim platform is developed based on UE. During the development process, it has a collision engine mode. This example shows the detailed process of two aircraft from takeoff to collision.**
- **For detailed operations and experimental results, see [1.BasicExps\e5_CollisionExpAPI\4.CollUDPModeAPI_Mat\Readme_En.pdf]**



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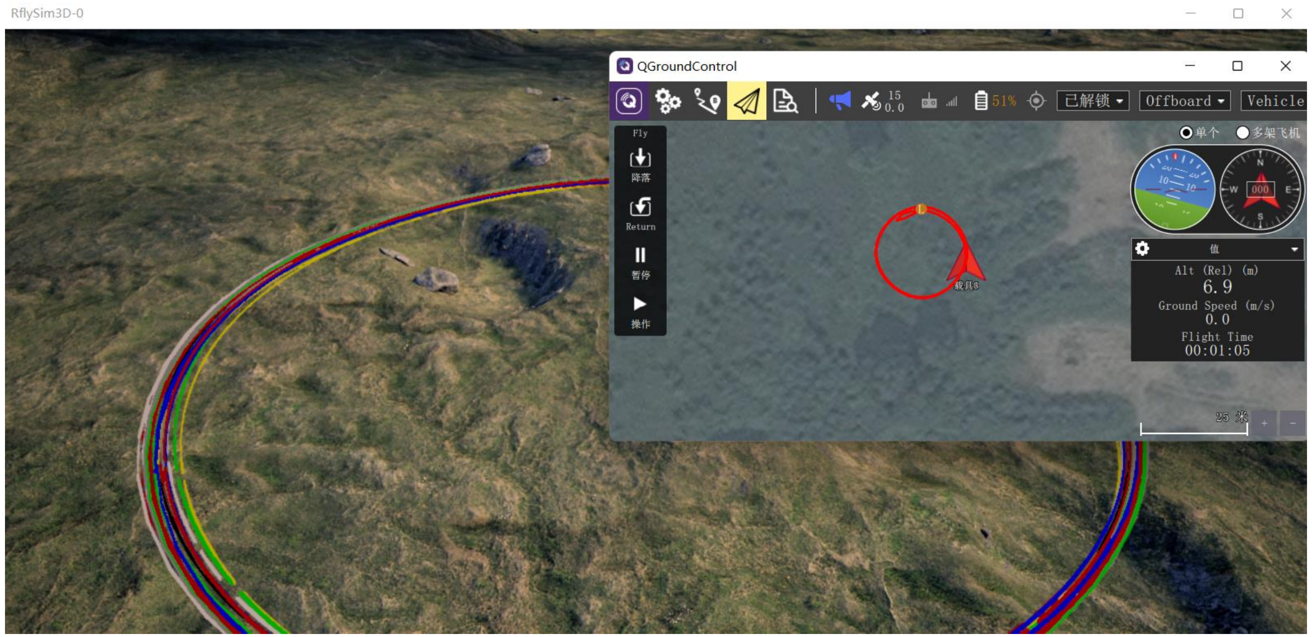
4. Advanced interface experiment

- **4.1.1 Eight-machine circle drawing experiment in UltraSimple mode of communication interface**
- **Through the RflyUdpFast transmission module provided by the platform, the status information of the drone is received, and then Simulink modeling is performed to control the local position motion of a single drone, and the control instructions are sent to the module, and then simulated.**
- **For detailed operations and experimental results, see 2.AdvExps\e1_RflyUdpSwarmAdvExp\Readme_en.pdf**

4. Advanced interface experiment

- **4.1.2 8-machine SITL simulation experiment**
- **By using the UDP communication function interface of the RflySim platform, the drone aircraft takes off and then flies in concentric circles.**
- **For detailed operations and experimental results, see 2.AdvExps\e1_RflyUdpSwarmAdvExp\2.UDPSimple8Swarm_Py\Readme_En.pdf**

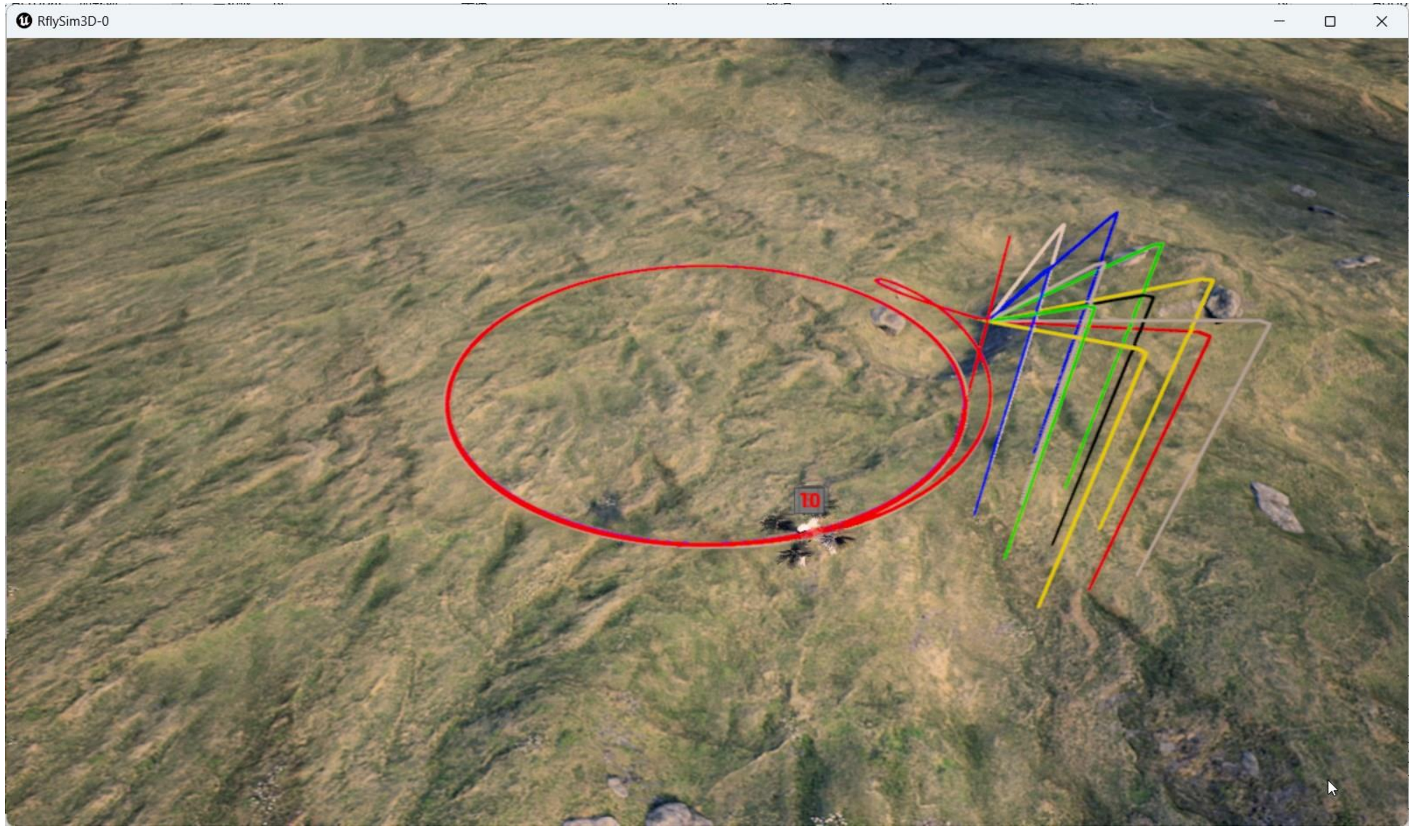


4. Advanced interface experiment

- **4.2 12-machine point cluster experiment**

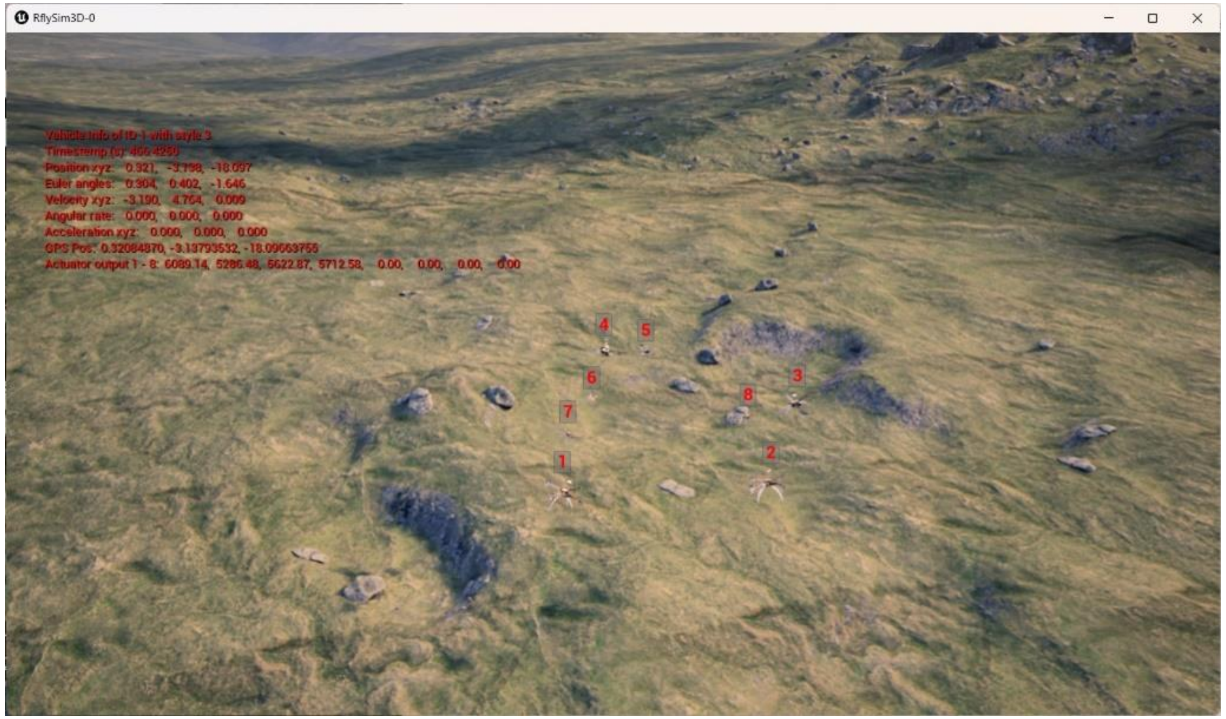
- **This experiment is based on the RflySim platform to realize the takeoff and circular flight of 12 particle model quad-rotor aircraft.**

- **For detailed operations and experimental results, see 2.AdvExps\e2_NoPX4SITL 12Swarm\Readme_En.pdf**



4. Advanced interface experiment

- **4.3.1 Distributed LAN broadcast communication 8-machine simulation experiment**
- **This experiment enables two computers (hereinafter collectively referred to as computer A and computer B) in a local area network to jointly fly eight aircraft in a circle.**
- **For detailed operations and experimental results, see 2.AdvExps\e3_DistributedLANSwarm\1.BroadNetSwarm_Mat\Readme_En.pdf**



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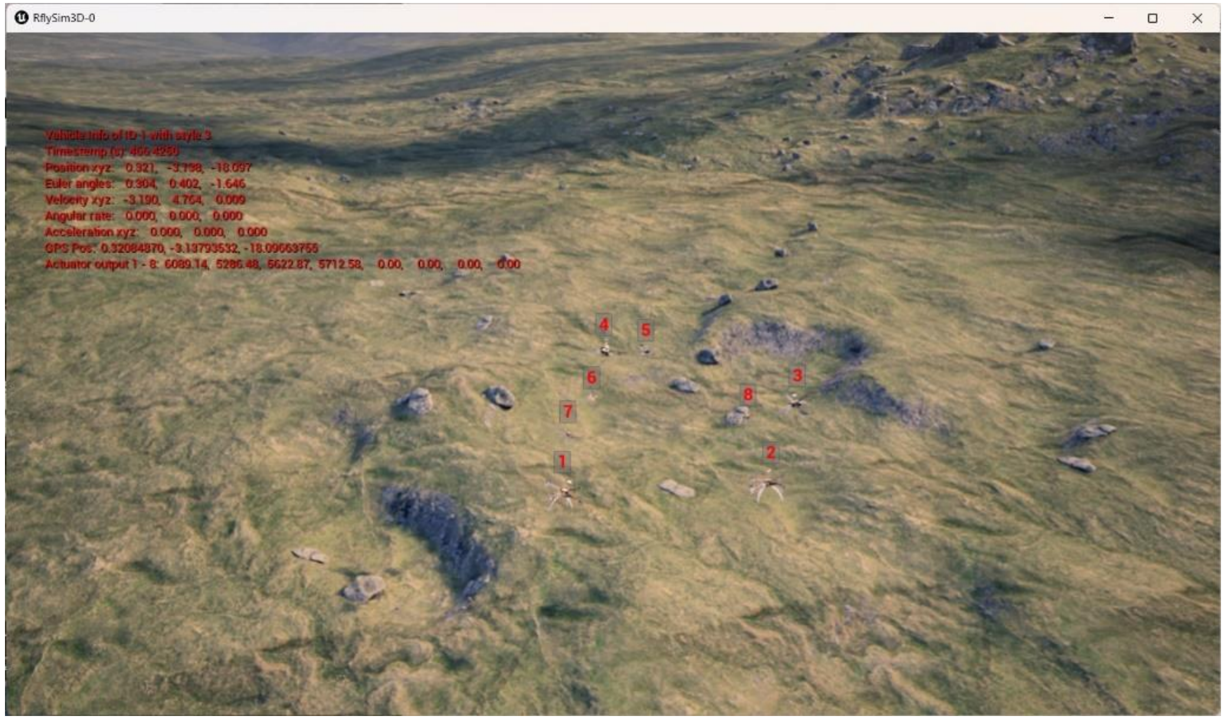
4. Advanced interface experiment

- **4.3.2 Distributed LAN point-to-point communication 8-machine simulation experiment**
- **This experiment enables two computers (hereinafter collectively referred to as computer A and computer B) in a local area network to jointly fly eight aircraft in a circle.**
- **For detailed operations and experimental results, see [2.AdvExps\e3_DistributedLANSwarm\2.UseIPNetSwarm_Mat\Readme_En.pdf]**



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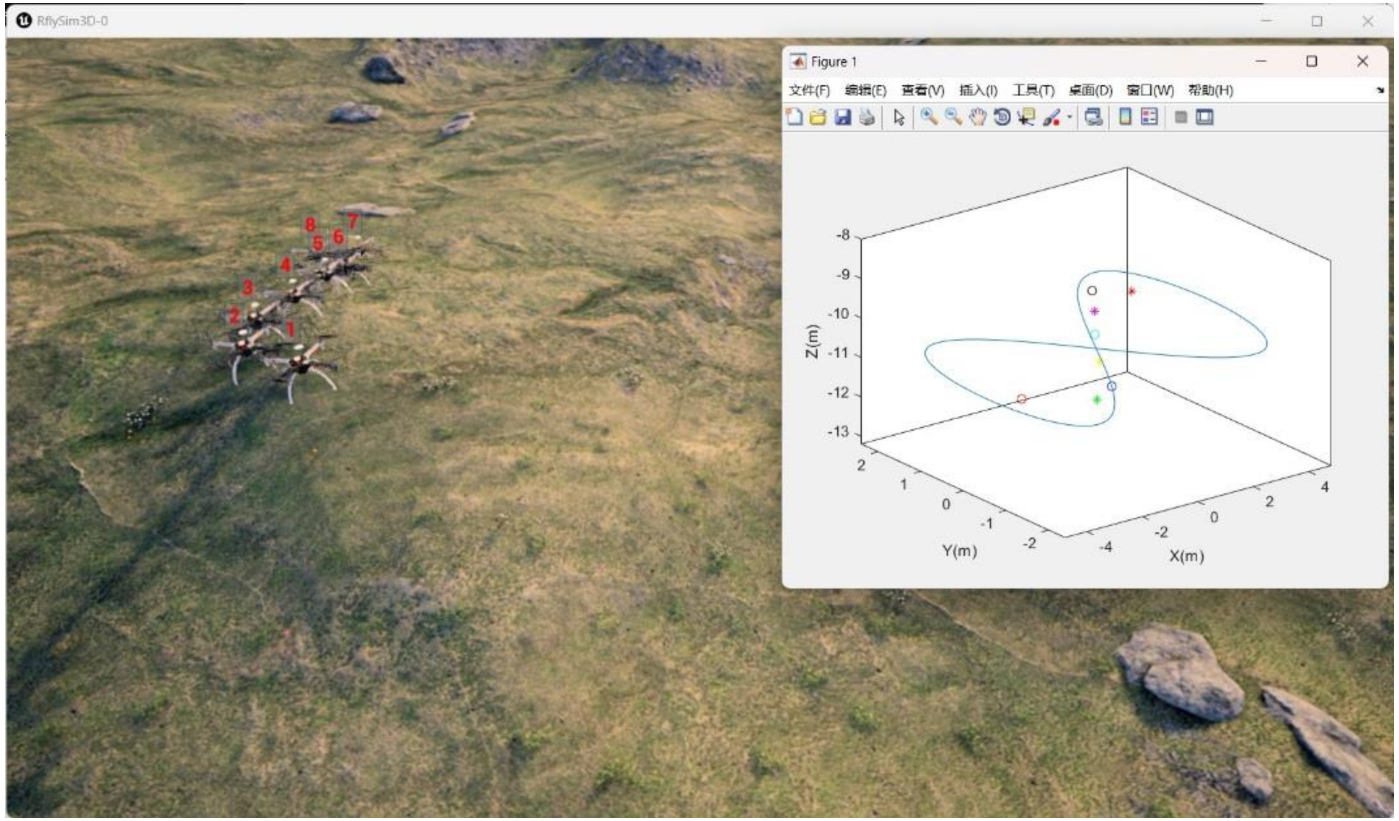
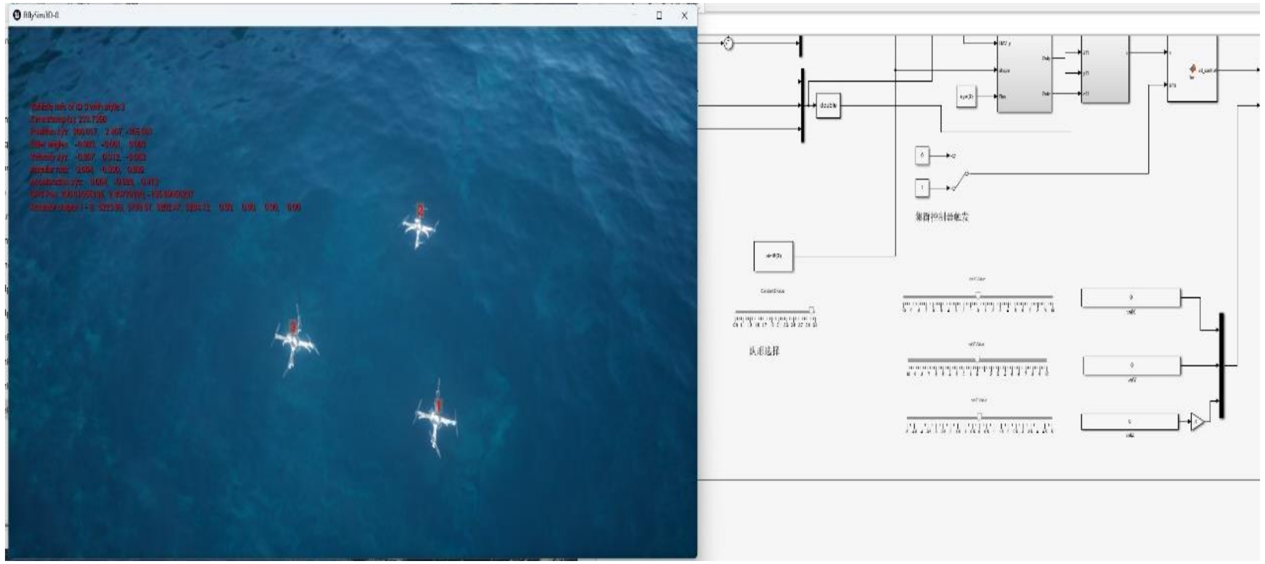
5. Advanced case experiments

- **5.1.1 Simulation experiment of 8 aircraft flying in a figure-8 formation**
- **Through the RflyUdpFast transmission module provided by the platform, based on MATLAB/Simulink, the flight control experiment of controlling eight quad-rotor drones in a figure-eight formation was realized.**
- **For detailed operations and experimental results, see 2.AdvExps\e4_SwarmFormCollCtrl\1.UAV8Swarm3D_Mat\Readme_en.pdf**



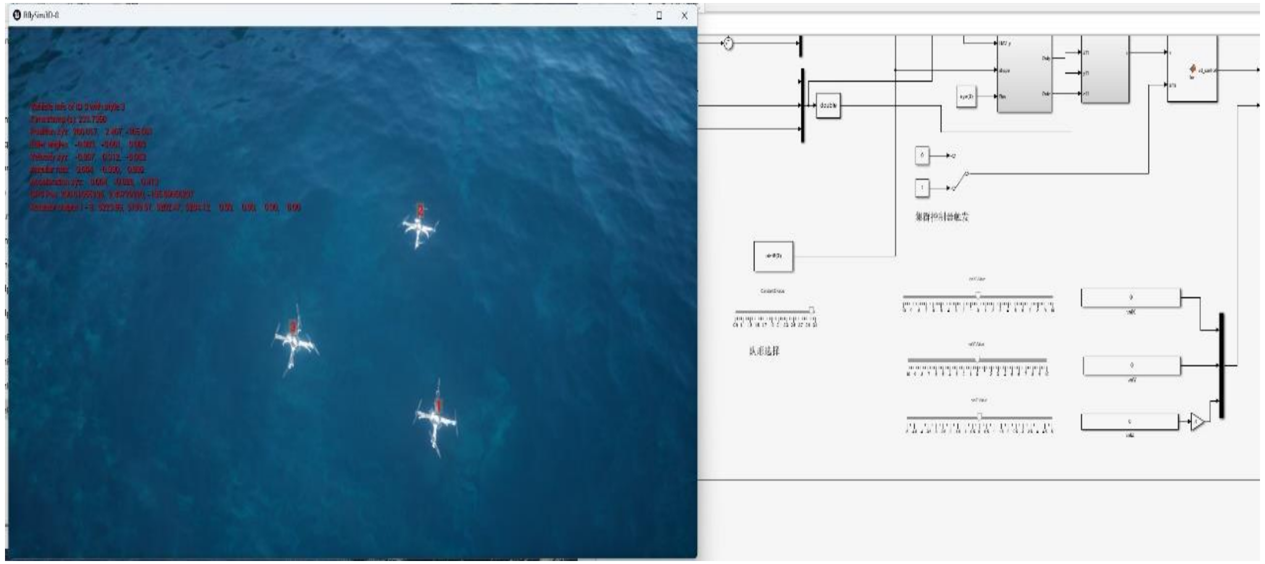
5. Advanced case experiments

- **5.1.2 Controlling the speed of the aircraft under automatic anti-collision to conduct cluster formation simulation experiments**
- **In this experiment, software and hardware-in-the-loop simulation were used to demonstrate the transformation and formation functions of different UAV formations.**
- **For detailed operations and experimental results, see [2.AdvExps\e4_SwarmFormCollCtrl\2.SwarmBodyVelCtrlColl_Mat\Readme_en.pdf]**



5. Advanced case experiments

- **5.1.3 Controlling the earth's speed (NED coordinate system) under automatic anti-collision to conduct cluster formation simulation experiments**
- **In this experiment, software and hardware-in-the-loop simulation were used to demonstrate the transformation and formation functions of different UAV formations.**
- **For detailed operations and experimental results, see 2.AdvExps\e4_SwarmFormCollCtrl\3.SwarmEarthVelCtrlColl_Mat\Readme_en.pdf**



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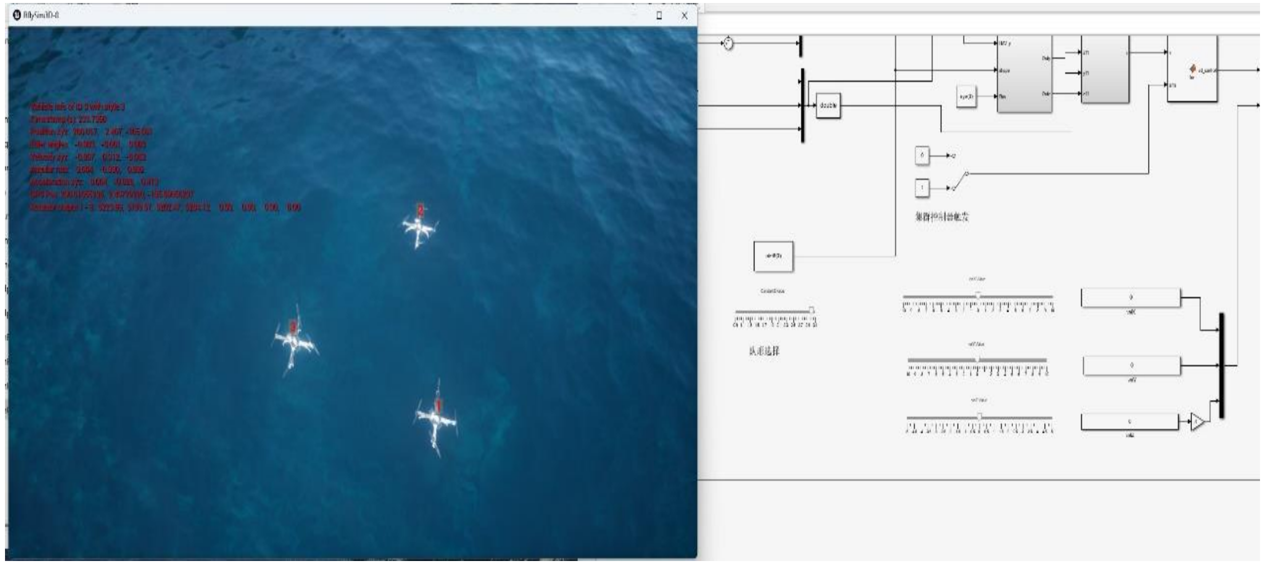
5. Advanced case experiments

- **5.1.4 Cluster formation simulation experiment (UDP mode) controlling earth speed (NED coordinate system) under automatic anti-collision**
- **In this experiment, software and hardware-in-the-loop simulation were used to demonstrate the transformation and formation functions of different UAV formations.**
- **For detailed operations and experimental results, see** **2.AdvExps\e4_SwarmFormCollCtrl\4.SwarmEarthVelCtrlCollUdp_Mat\Readme_en.pdf**



飞思实验室

outline

1. Experimental platform configuration
2. Introduction to key interfaces
3. Basic experimental cases

   (free version)
4. Advanced interface experiment

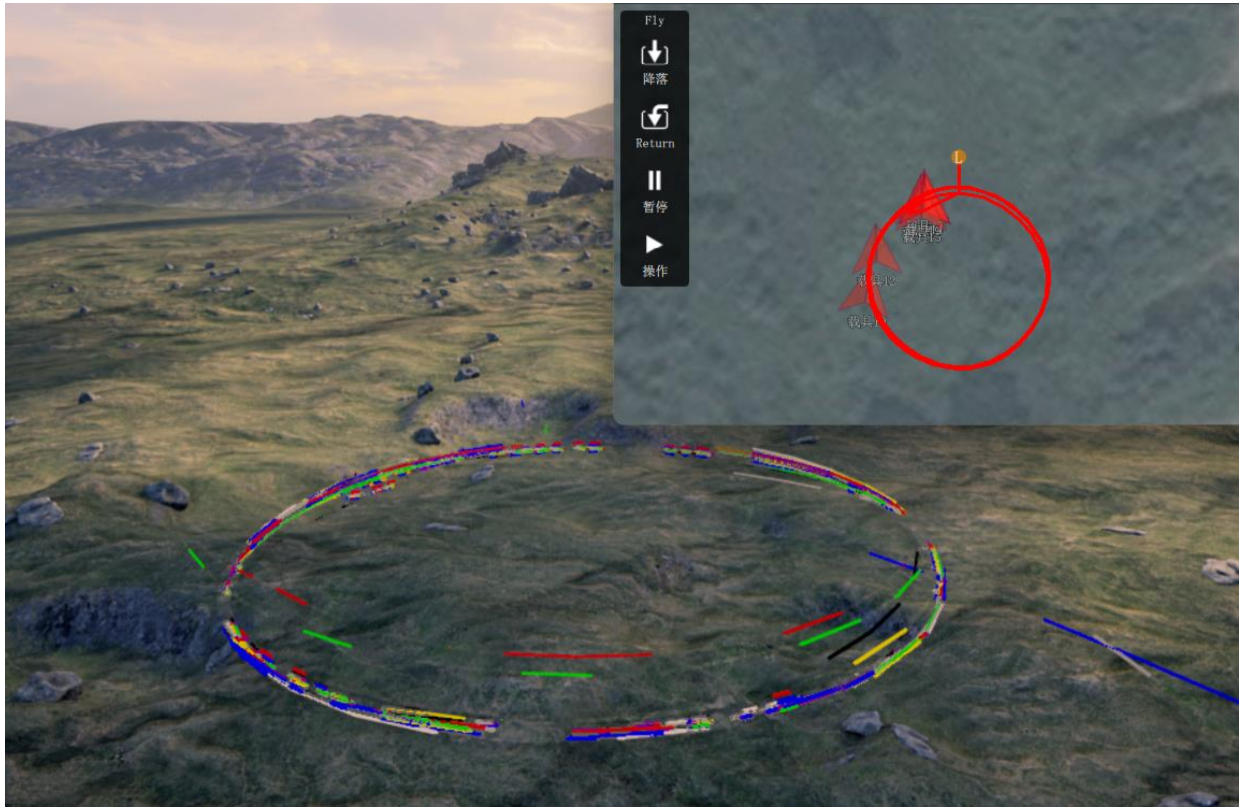
   (personal version)
5. Advanced case experiments

   (collection version)
6. Extended case

   (full version)
7. Summary

6. Extended cases

- **6.1 Distributed LAN point-to-point communication 16-machine simulation experiment**



- **This experiment enables two designated computers in the local area network (hereinafter collectively referred to as computer A and computer B) to jointly fly eight aircraft in a circle.**
- **For detailed operations and experimental results, see 3.CustExps\e1_UDPSimple16Swarm2PC_Py\Readme_En.pdf**

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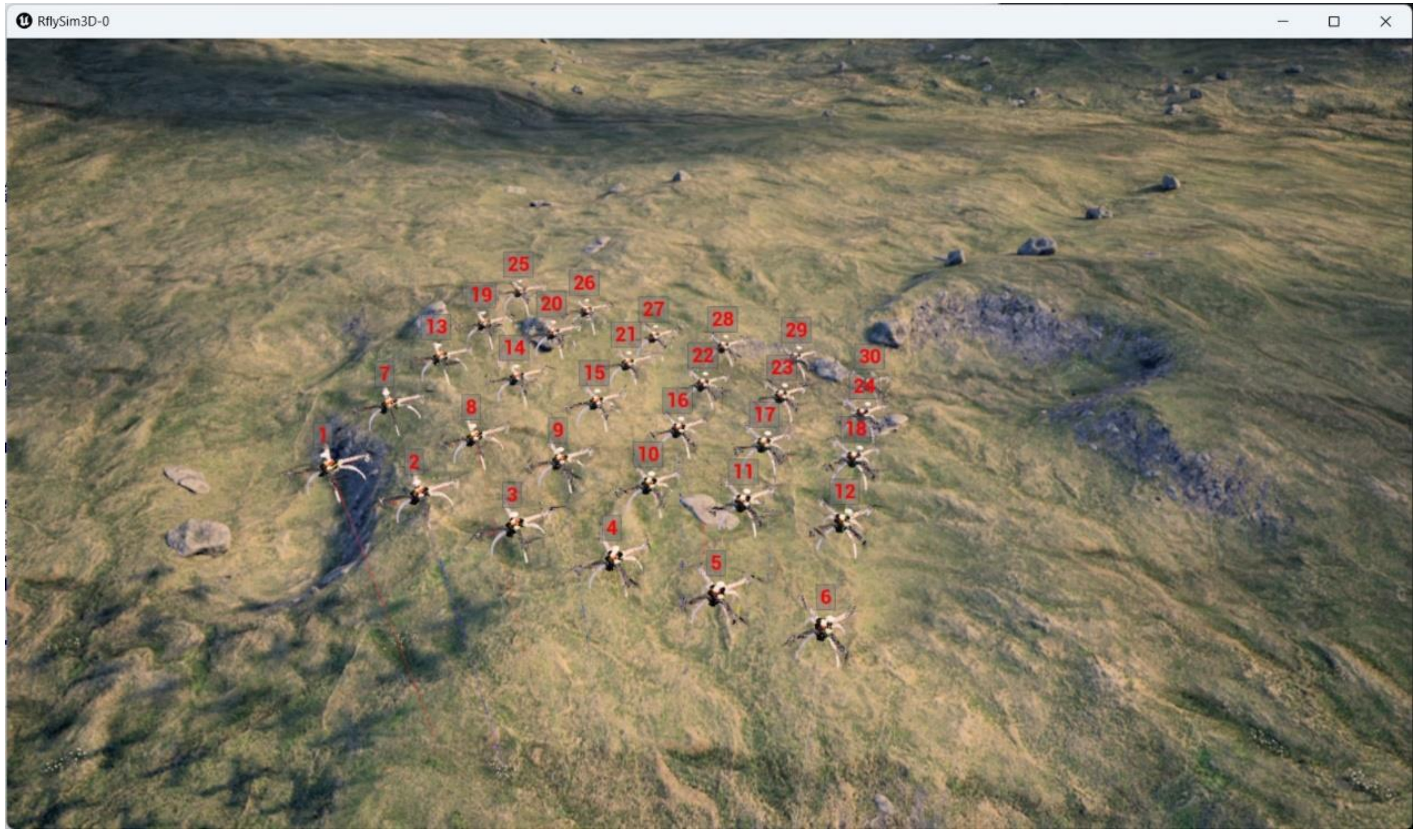
6. Extended cases

- **6.2.1 30-machine point cluster experiment**

- **This experiment is based on the RflySim platform to realize the take-off and circular flight of 30 particle model quad-rotor aircraft.**

- **For detailed operations and experimental results, see 3.CustExps\e2_NoPX4SITLSwarm\1.NoPX4SITL30Swarm\Readme_En.pdf**



6. Extended cases

- **6.2.2 100-machine point cluster experiment**

- **This experiment is based on the RflySim platform to realize the takeoff and circular flight of 100 particle model quad-rotor aircraft.**

- **For detailed operations and experimental results , see 3.CustExps\e2_NoPX4SITLSwarm\2.NoPX4SITL100Swarm\Readme_En.pdf**

6. Extended cases

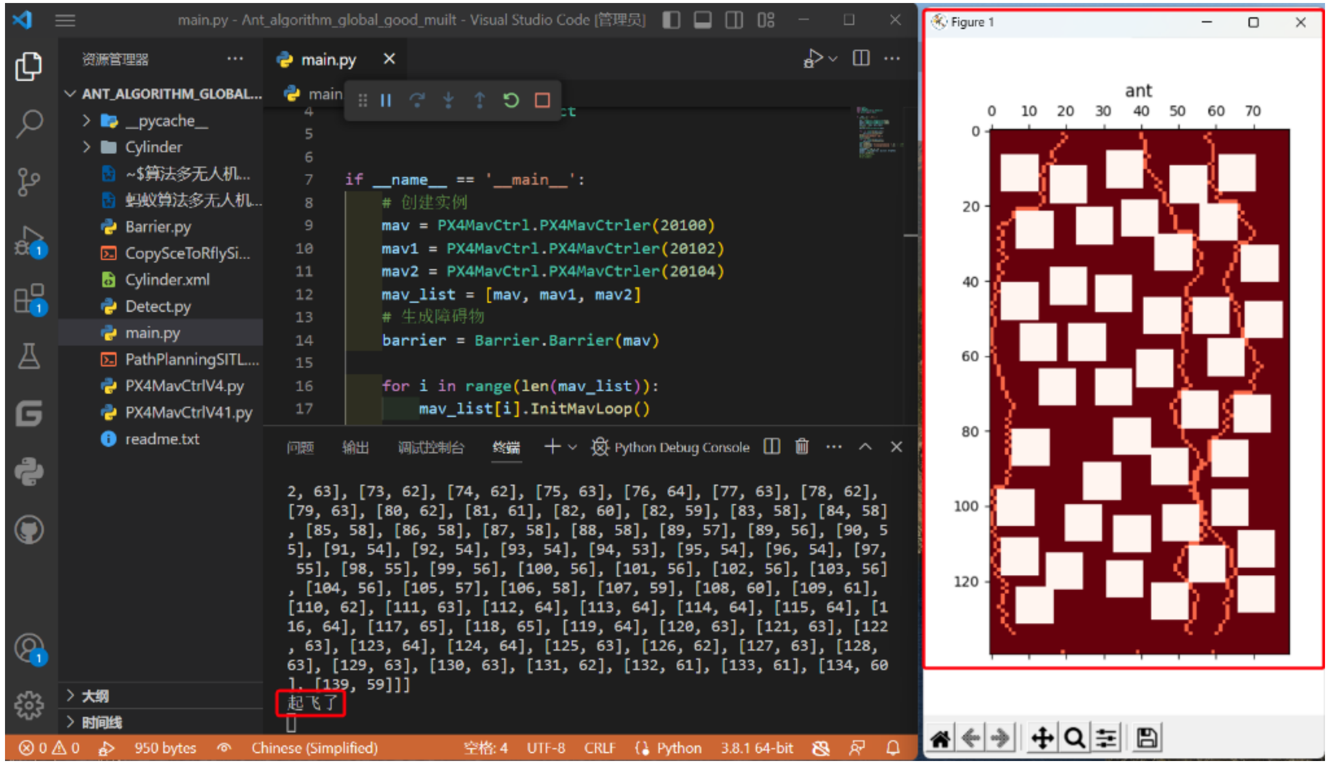
- **6.2.3 200-machine point cluster experiment**

- **This experiment is based on the RflySim platform to realize the takeoff and circular flight of a quadcopter with 200 particle models on two computers in a local area network.**

- **For detailed operations and experimental results, see [3.CustExps\e2_NoPX4SITLSwarm\3.NoPX4SITL200Swarm2PC\Readme_En.pdf]**

6. Extended cases

- **6.3.1 Ant algorithm multi-UAV path planning experiment**
- **A feasible and optimal path is planned through the ant algorithm. This path needs to meet the requirements of obstacle avoidance and collision avoidance.**
- **For detailed operations and experimental results, see [3.CustExps\e3_AISwarmCtrlExp\1.AntAlgorithmMutUAVPathPlan\Readme_En.pdf]**

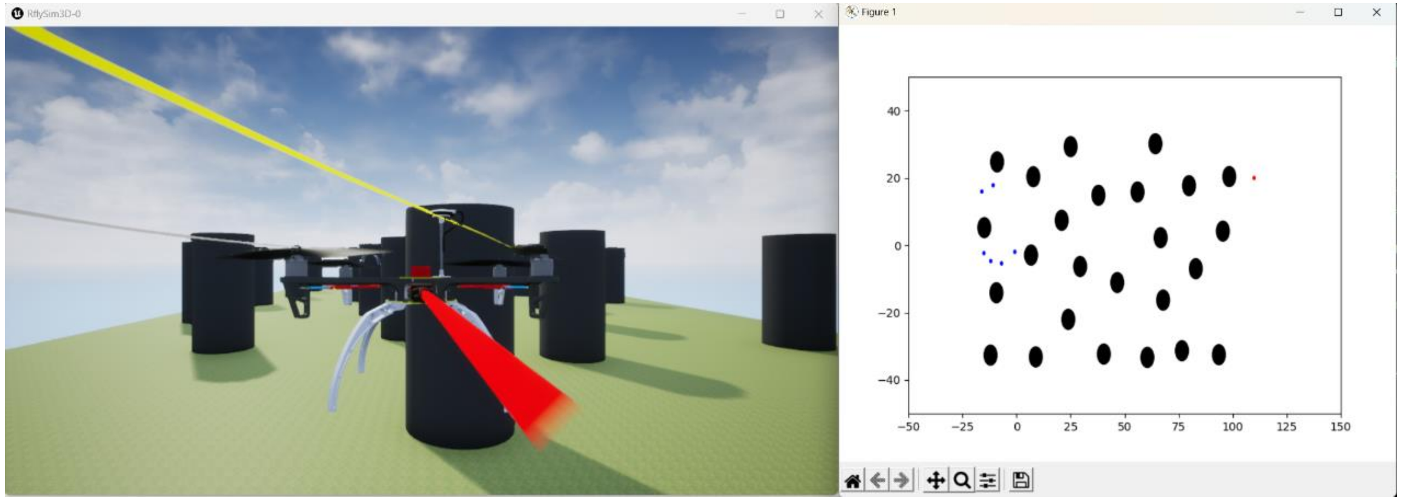


6. Extended cases

- **6.3.2 Olfati-Saber clustering algorithm**

- **The Olfati-Saber algorithm is used to achieve obstacle avoidance, collision avoidance, and clustering of multiple UAVs toward the target point.**

- **For detailed operations and experimental results, see 3.CustExps\e3_AISwarmCtrlExp\2.Olfati_SaberSwarmUAVObsAvoid\Readme_En.pdf**

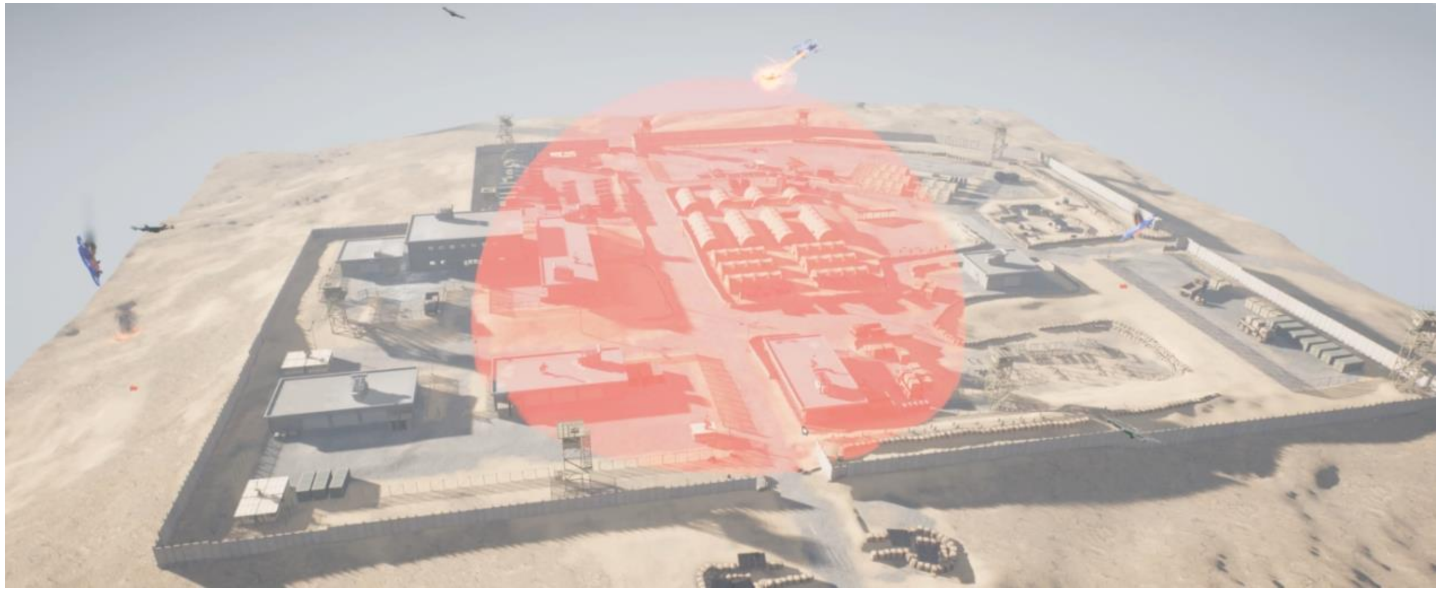


6. Extended cases

- **6.3.3 UAV area defense**

- **Using deep reinforcement learning to train the drone defense model enables the use of fewer drones to defend against attacking drones and achieves good defensive results.**

- **For detailed operations and experimental results, see 3.CustExps\e3_AISwarmCtrlExp\3.MultiUAVRegionDefense\Readme_En.pdf**



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outline

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7. Summary

- **This lecture mainly explains the cluster communication and cluster control of UAVs. It is divided into three parts: basic experiments, advanced experiments and extended cases. It can realize local area networking, UAV cluster communication and UAV formation control.**

If you have any questions, please go to https://doc.rflysim.com/ for more information.

More tutorials on RflySim

Scan the QR code for consultation and communication

RflySim technical exchange group

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Thanks！