Development and Practice of Intelligent Unmanned Cluster System

Full Stack Development Case Based on RflySim Platform

Lesson 2 Experimental Platform Configuration

飞思实验室

Curriculum resources

- **The video address of this PPT public welfare course is:**
- **Software usage and configuration:**https://www.bilibili.com/video/BV1UL4y1F7NL
- **Hardware usage and configuration:** https://www.bilibili.com/video/BV1qY4y187NZ
- **More curriculum resources:**https://space.bilibili.com/3493283546269949?spm_id_from=333.1007.0.0
- 或使用手机扫码观看：

Use and configuration of software

Use and configuration of hardware

RflySim More Tutorials

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Outline

1. Platform Introduction and Installation
2. Software and hardware overview and configuration
3. Soft and hard basic use experiment
5. Experimental preview in the following chapters
6. Future functions and prospects
7. Summarize

To purchase the teaching AIDS required for this course (configured and ready to use, you can skip the PPT hardware configuration part), you can visit the following Taobao shop link, or Taobao App scans the QR code on the right side

https://shop212206553.taobao.com/

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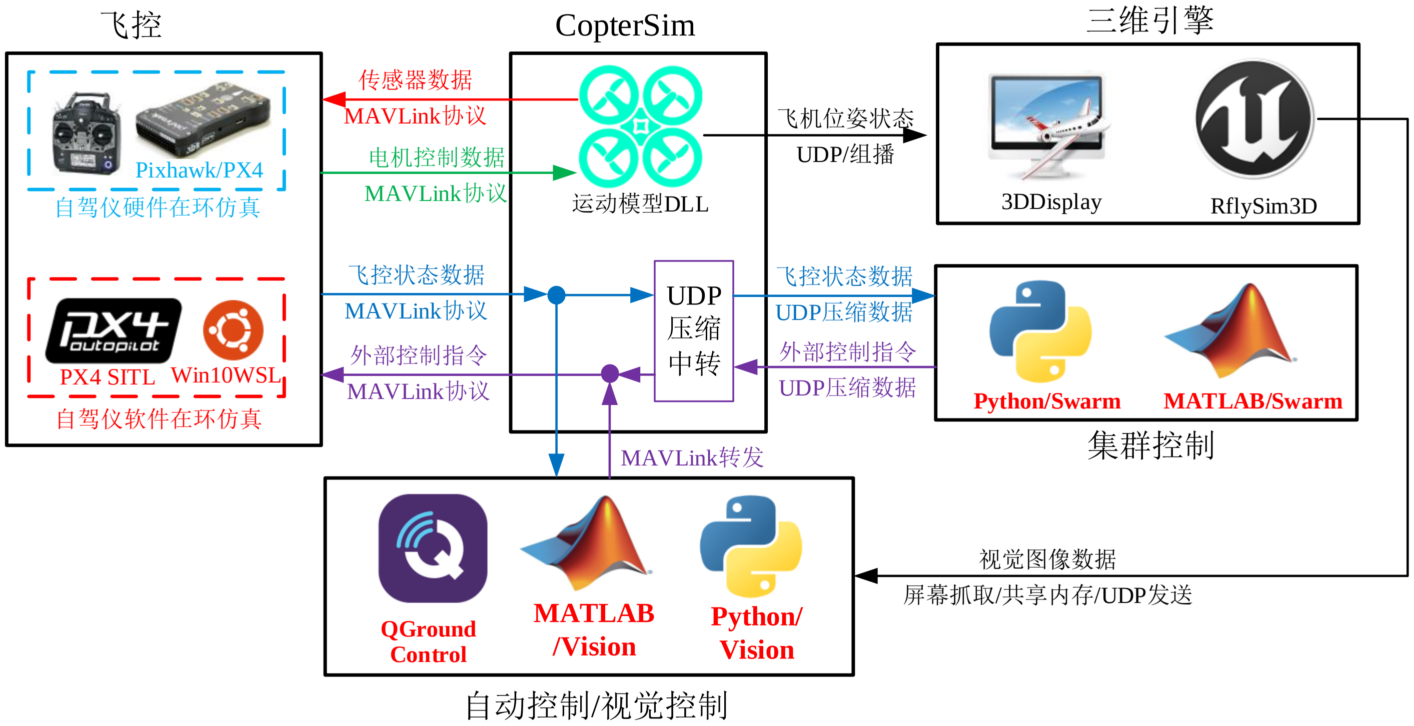
RflySim教程

1. Platform Introduction and Installation

Introduction to the 1.0 RflySim Platform:

RflySim is a Pixhawk/PX4 and MATLAB/Simulink ecosystem or tool chain for research and education, using Model-Based Design (MBD) ideas for control and safety testing of unmanned systems.



1. Platform introduction and installation

- Version difference description (see link or QR code for detailshttp://rflysim.com/doc/RflySimVersions.xlsx）：
- The RflySim platform is currently available in three versions:Basic (free), Premium (free)AndPremium full version (paid, please consultservice@rflysim.com）。
- Basic editionAs an experimental platform, it corresponds to the book Design and Control Practice of Multi-rotor Aircraft. The installation package is small in size and only contains the functions developed by Simulink, the underlying algorithm of PX4.
- Premium experience editioninBasic editionFunctions such as aircraft dynamics model development, UE4 3D scene development, visual control development and cluster algorithm development are added, but the number of clusters and distributed simulation functions are limited.
- Advanced full editioninThe Trial EditionAdded the latest UE5 engine, global large-scale scene simulation, distributed LAN cluster visual simulation and other functions.

1. Platform introduction and installation

1.1 Checking the computer Configuration. To be able to run the RflySim platform, the following computer configurations are recommended:

- **System**: Windows 10 x64 (The version is greater than or equal to 1903)
- **CPU**: Intel i5 10 generation processor or above, or equivalent performance AMD processor
- **Graphics card**: Intel integrated graphics UHD 620 and above, or equivalent performance AMD graphics card
- **Memory**: Capacity 16G or above, frequency DDR3 1600MHz or above
- **Hard disk**: Remaining capacity 40G or above (SSD recommended)
- **Display**: resolution 1080P (1920*1080) and above (dual screen recommended)
- **Interface**: at least one USB Type A interface (available expansion cable)
- **MATLAB**: 2017b or later (2017b recommended)

Note: The computer configuration should be as high as possible, low-configuration computers can also run the Demo of this platform, but there may be unstable control, poor experimental results and other problems. Please install MATLAB in advance.

Note: This platform is suitable for games or game consoles, professional servers and graphics workstations are not compatible with this platform, there will be jitter and stuttering.

1. Platform introduction and

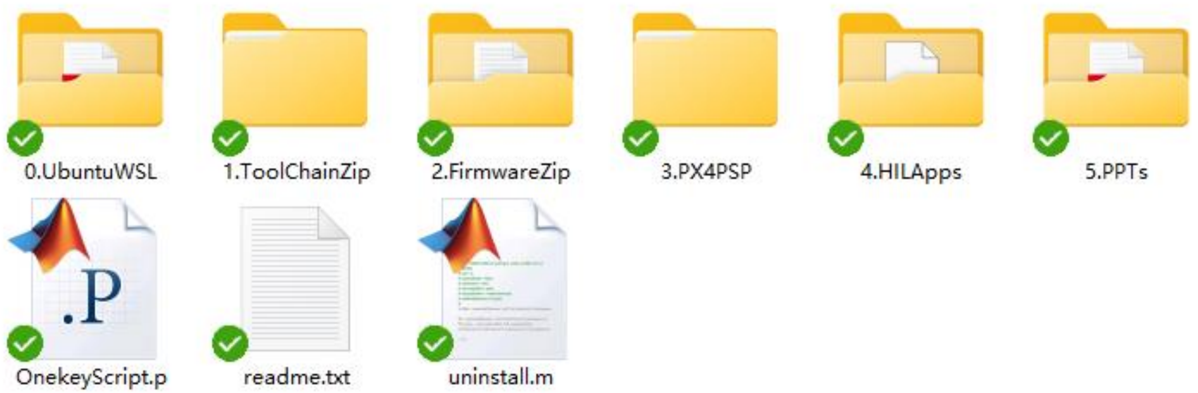
Attention:

- The basic version and the Advanced Experience version can be mirrored by filling in the mailboxhttps://rflysim.com/download Get the cloud disk download link.
- For the full version download link and registration code please consultservice@rflysim.com
- The cloud disk link and password we share will not change, but the installation package inside will be updated frequently, so the cloud disk installation package update time as the version base.

1.2 Obtaining and Installing Software

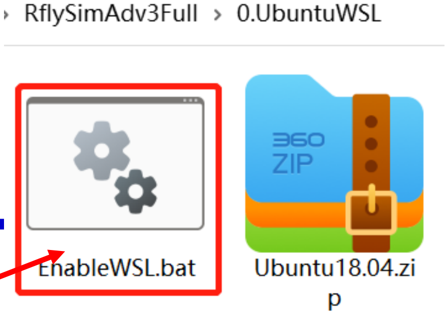
- Obtain the installation package: Obtain the latest.iso image from an official source（The full version is RflySimAdv3Full-****.iso, and the experience version is RflySimAdvFree-****.iso, after which **** indicates the version number）You can right-click the mouse - open mode -Windows Explorer to load the image (or use the decompression software to decompress, or use the virtual drive to load), so as to obtain the installation package folder shown on the right.

Scan the code to see the RflySim platform video installation tutorial



Note: The "5.PPTs" folder has the latest PPT tutorial, after running the installation script will be copied to the PX4PSP directory, readme.txt has the version number, update time and update content

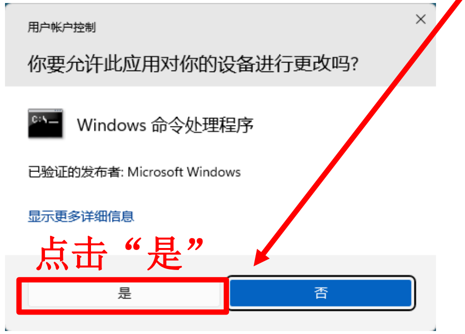
1. Platform introduction and installation

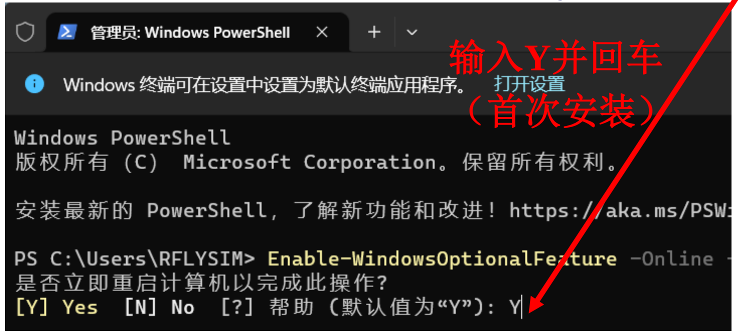


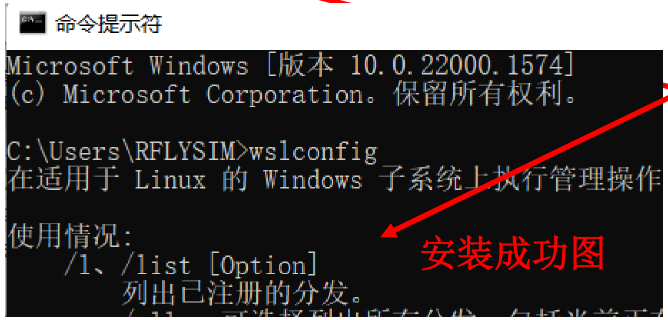
1.3 Enabling the WSL subsystem function.

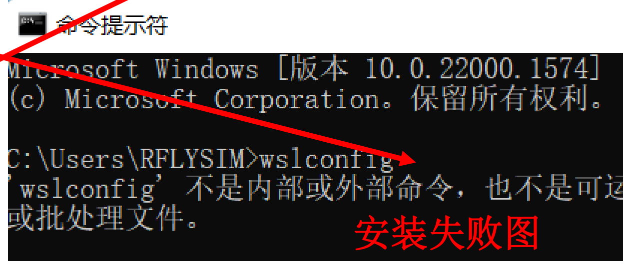
1. For Win10 and Win11 systems: Win10WSL compiler is recommended, and the following operations need to be performed first:

- Start WSL subsystem function: double-click the script "0.UbuntuWSL\ EnableWSL.bat" (close the antivirus software first to avoid interception), and click "Yes" in the "User Account Control" window to automatically start WSL subsystem.
- Note: If this command is executed for the first time on the PC, enter Y in the pop-up window and press Enter to confirm the installation and restart the PC. If this command is not executed for the first time, the window automatically closes and you do not need to restart the PC.。
- Note: If a problem occurs, such as a flash exit, enter the wslconfig command in the CMD window to check whether the installation is successful. If no command is displayed, the installation fails. Close the antivirus software and follow the 0.UbuntuWSL\ readme.pdf process to start the software manually.









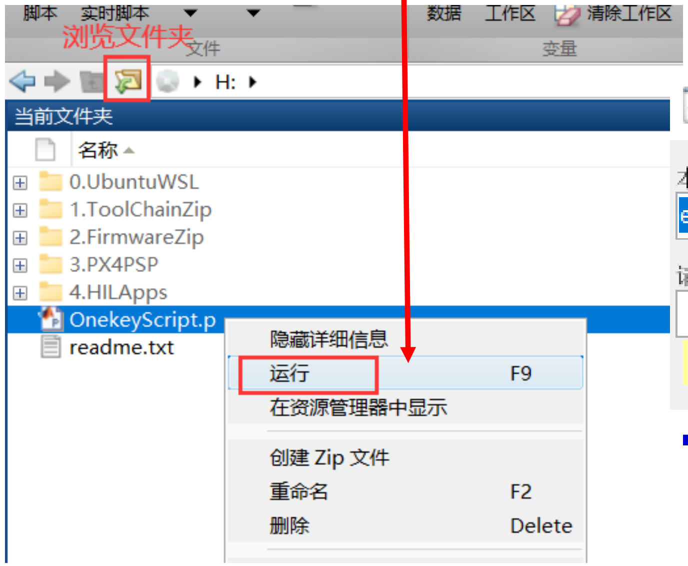
2. For Win7 systems (or Win10WSL compiler installation failure) : Only use the Cygwin compiler. You can skip the previous step and go directly to the one-click installation script page in the following article, and select 3 when entering "PX4 firmware compiler" : Cygwin compiler.

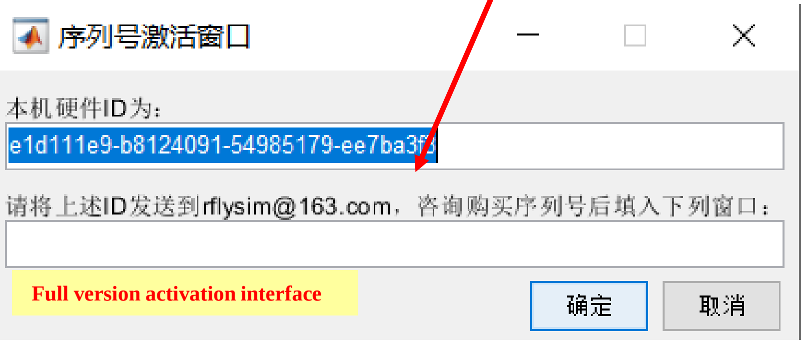
1. Platform introduction and installation

Note: To improve the installation speed and ensure the smooth completion of the installation, please turn off all anti-virus software, and Windows 10/11 Security Center "real-time protection"

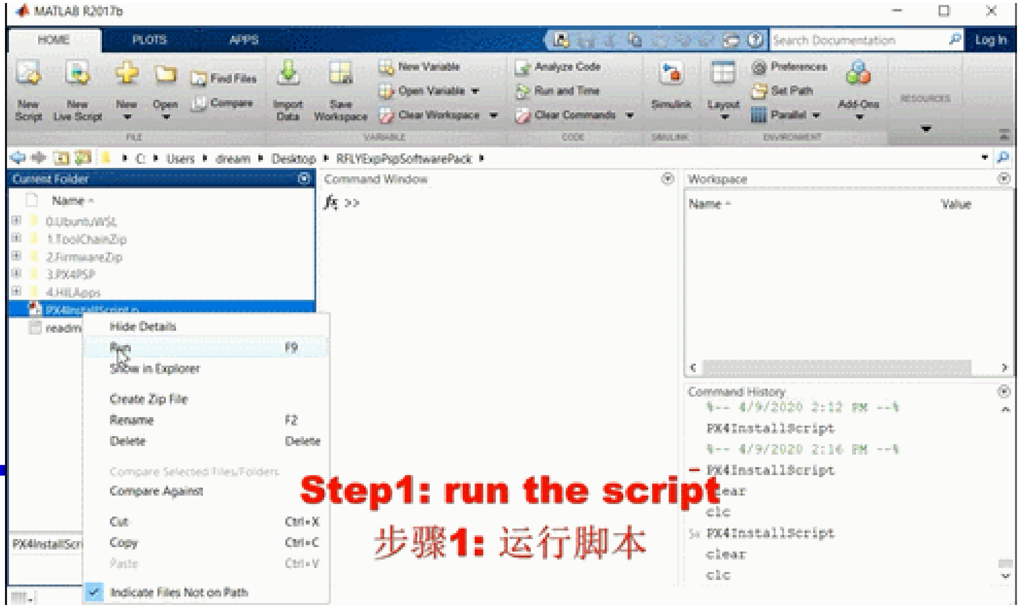
1.4 One-click Installation script

- Click the "Browse folder" button in MATLAB, locate the folder you just loaded the iso image, and right mouse buttonOnekeyScript.p, click"operation"Button (or type the OnekeyScript command in the window)
- The full version will pop up the activation page, get the serial number and enter it.Experience version does not pop up activation window no need to enter the serial number!
- Then the installation page will pop up as shown in the right picture (Please follow the readme.txt instructions in the installation package to close the antivirus software before installation).





Full version activation interface



Step1: run the script
步骤1：运行脚本

1. Platform introduction and installation

Note: Win7 system, firmware compiler choose 3: Cygwin can (limited to full version), also applicable to WSL installation can not be installed on the user.

1.5 Recommended Installation Configuration - First Run

- To install the platform for the first time (or restore the platform configuration), you can directly use the default configuration on the right picture, select "Yes", click "OK" to install with one click;Users of low-level flight control development can be modified according to needs:

1. For the underlying development of Pixhawk 4 flight control, select the compile command“px4_fmu-v5_default”(If you have other flight control hardware, please modify it yourself);
2. Use the newer PX4 firmware PX4-1.13.0, firmware version select "7" (top-level algorithm development requires ≥4 or ≥ 1.10 firmware);
3. Use the Win10WSL compiler, so choose "1" for the compiler; Note: Also can not install WSL subsystem, select "3" Cygwin (suitable for Win7+), but there is a long-term running instability problem, not recommended this way.
4. Whether to mask PX4 output Select"Yes"。 This option does not mask the output of the PX4_SITL controller, so software simulation can be performed normally.。
5. All others are selected by default when you install them for the first time"Yes", click again"Confirm"Button to start installation.

Note: If it is not the first installation but a platform update, you can select "No" for items 7 and 8 to save installation time.

Note: The free version of the firmware can only select 1 and 6, the compiler can only select 1 and 2. For support of other firmware, compilers, Win7 systems, and 3D scenarios, please contact service@rflysim.com Get full or incremental packages.

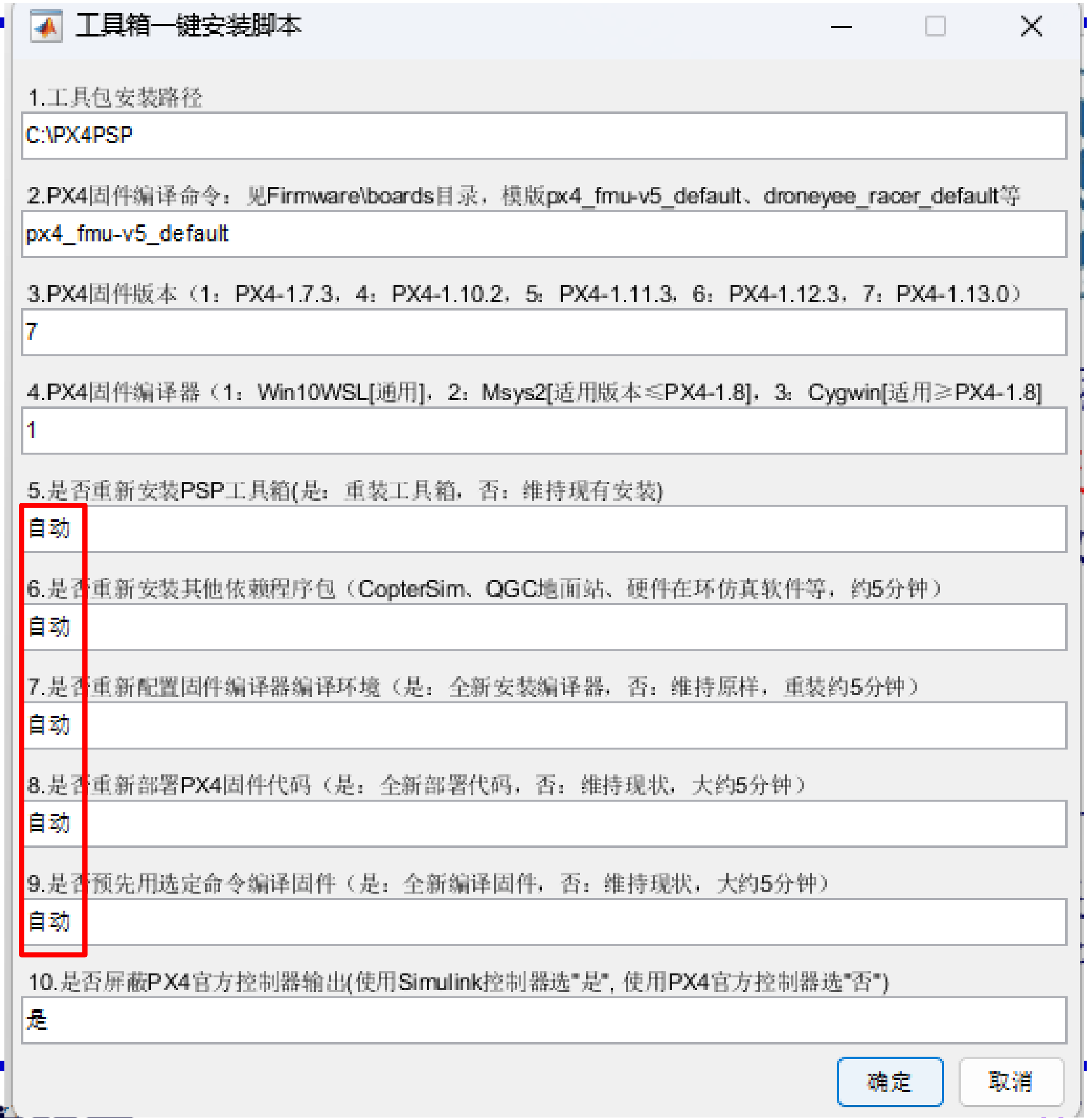
1. Platform introduction and installation

Emphasis: "Automatic" means that if the relevant functions are updated, the corresponding program will be automatically reinstalled in order to improve the installation speed of the platform, and can also be changed to "yes" or "no" according to their needs.

1.5 Recommended Installation and Configuration - Subsequent updates

- Download the new installation package and run the script again, as shown in the figure on the right
- You can see that the default option for items 5 through 9 has changed to "Automatic" instead of "yes" or "no".
- In automatic mode, the script automatically determines whether to update files according to the files in the installation package, which reduces the difficulty of use, speeds up the upgrade, and shorens the upgrade time.
- If you need to restore firmware, compilers, packages, etc., you can also change "automatic" to "yes" to achieve forced updates.。
- Note: "6. Whether... In addition to "automatic", "yes" and "no" for the input of "package", you can also specify the mandatory update module (comma separated) separately to save time. Optional modules include: CopterSim, drivers, FlightGear, QGroundControl, RflySim3D, RflySimAPIs, UE3DDisplay.

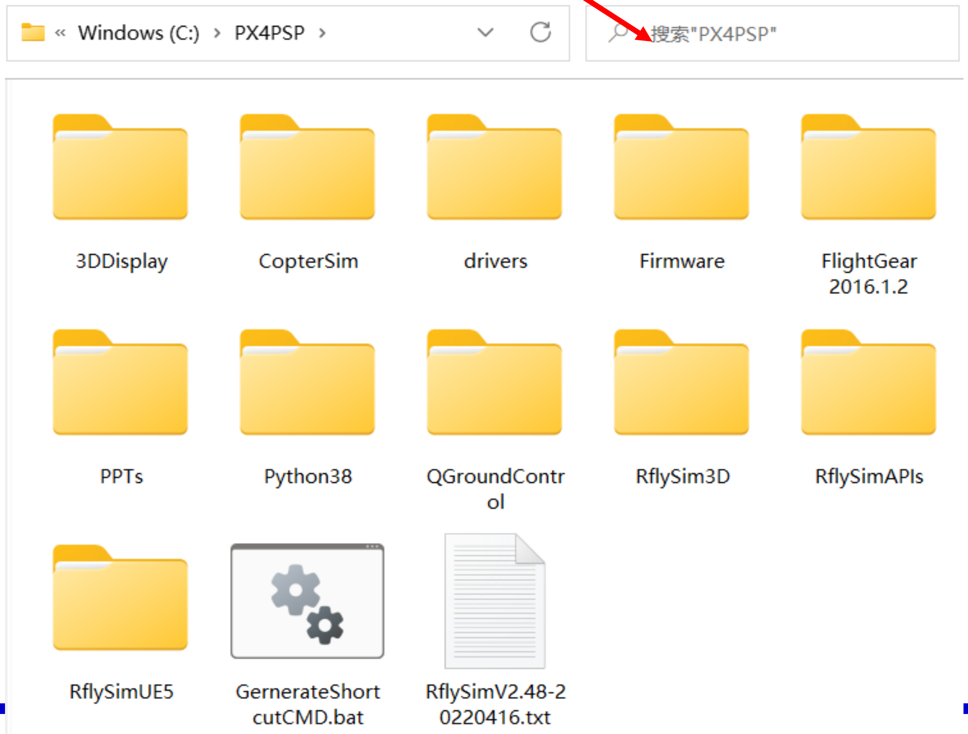
Note: If the blue Screen of death occurs when the platform is updated, please run the one-click script to uninstall the platform and install it again.

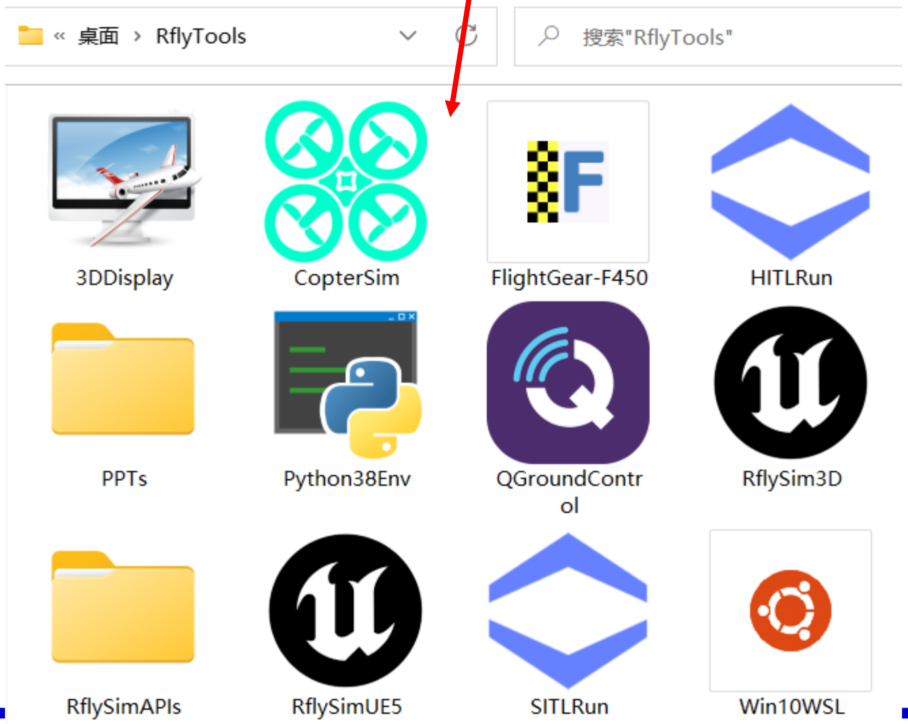


1. Platform introduction and installation

1.6 Windows Effects After Installation

- As shown below, under the installation directory (default is C:\PX4PSP) you can get a series of folders where“RflySimAPIs”The folder is the most important interface tutorial folder for advanced functions.
- As shown on the right, a series of shortcuts are available in the RflyTools folder on the desktop.



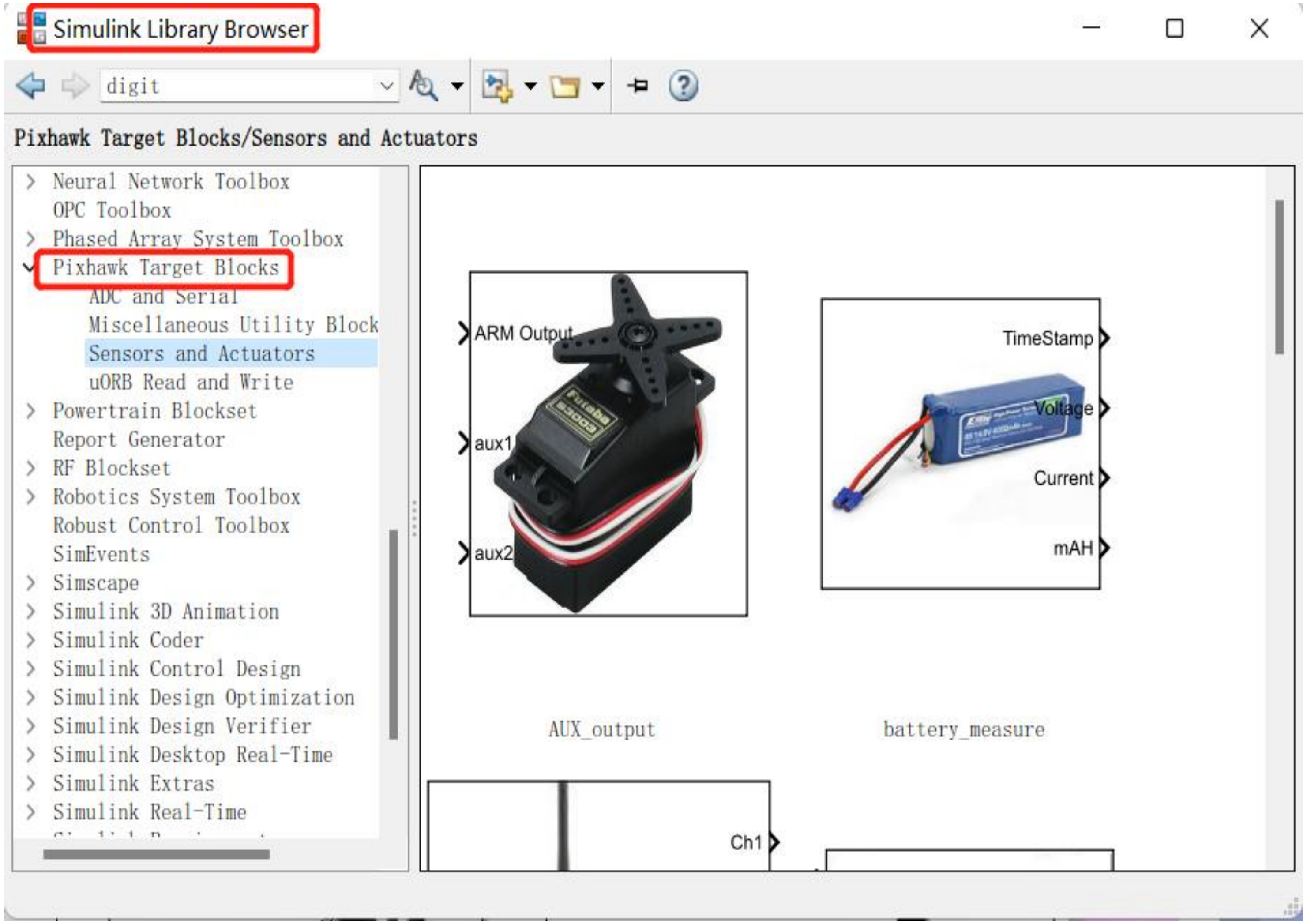


1. Platform introduction and installation

This function is only for low-level flight control algorithm development users, visual and cluster algorithm development users do not need to view.

1.7 Simulink Toolbox After Installation

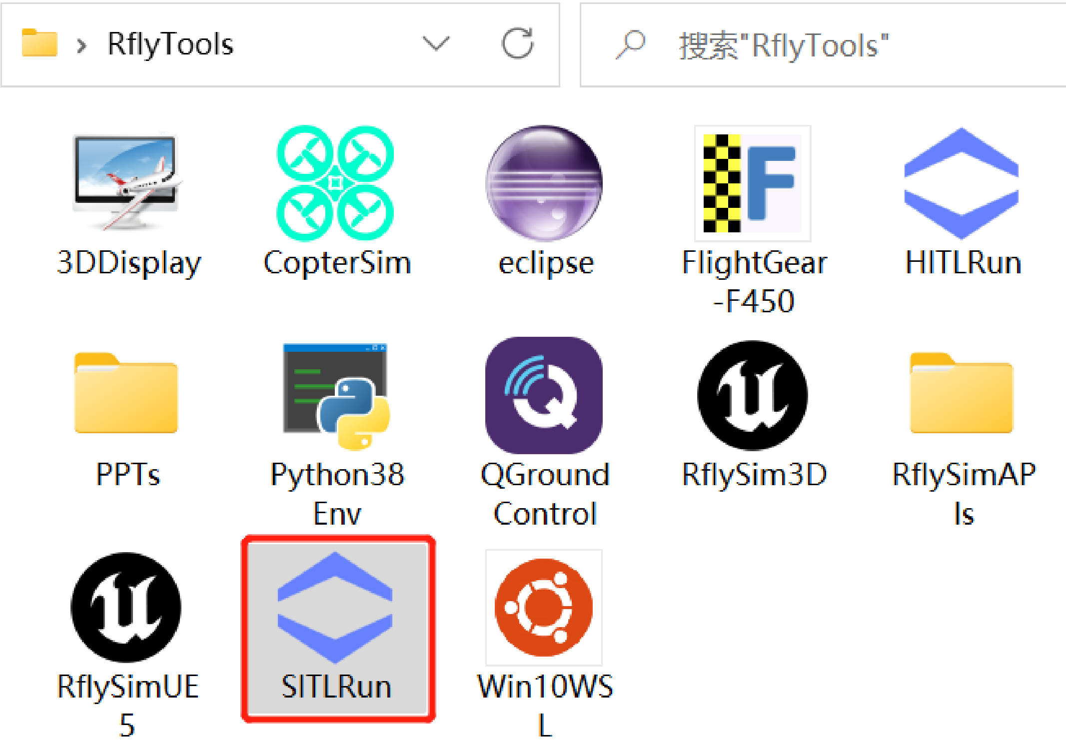
- Open MATLAB, create any new Simulink program,enter the Library browser page.
- As shown in the picture on the right, scroll down to see the Pixhawk Target Blocks toolbox, indicating that the installation is successful.
- Aiming at the development of the underlying flightcontrol algorithm, this function supports Simulink to design the flight control algorithm, and generates the code to upload to Pixhawk for hardware-in-the-loop simulation and real machine experiment.



1. Platform introduction and installation

1.8 Verifying the Platform Installation successfully

- **Go to the RflyTools folder on the desktop, double-click the SITLRun shortcut, type 1, and press Enter.**
- **When RflySim3D displays "*** EKF 3DFixed" (also displayed on CopterSim), it means that the ... cont**

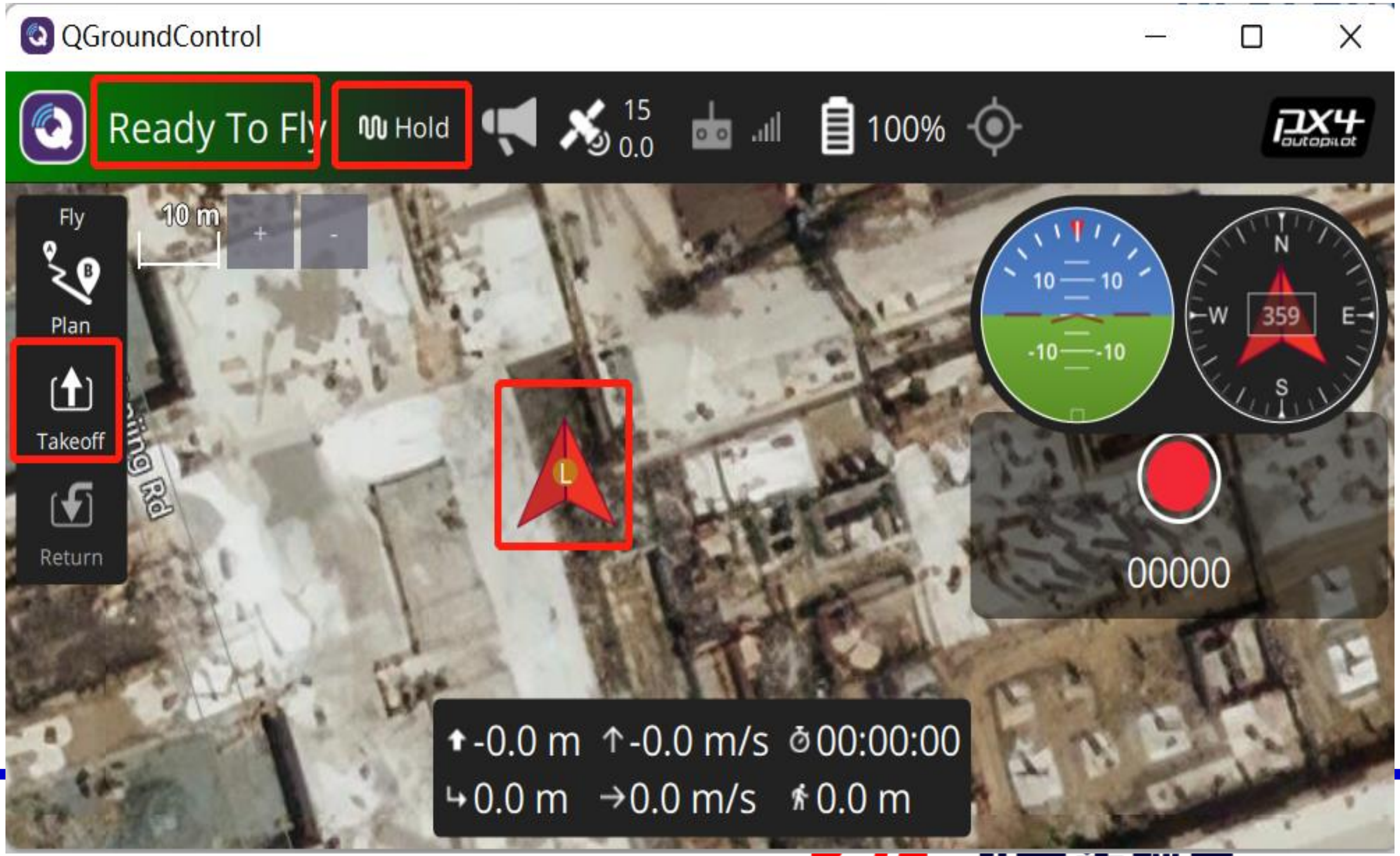


1. Platform introduction and installation

Note: If the bat script directly runs the plane jitter, please right-click the mouse and use the administrator mode to open the bat script! This allows for a higher running priority.

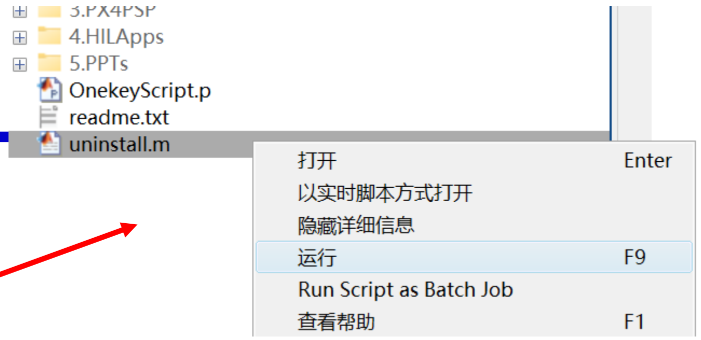
1.8 Verifying the Platform Installation successfully

- Go to the QGroundControl software and see the aircraft enter "Hold" mode and click the "Takeoff" button.
- The confirmation slider pops up and drags it to the far right to begin the automatic takeoff.
- If the plane can take off from the ground, the platform is configured correctly.



1. Platform introduction and installation

Note: You only need to perform this page if you need to uninstall the platform.

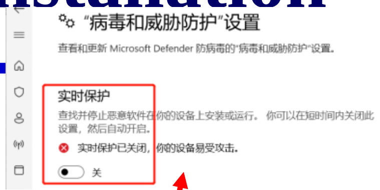


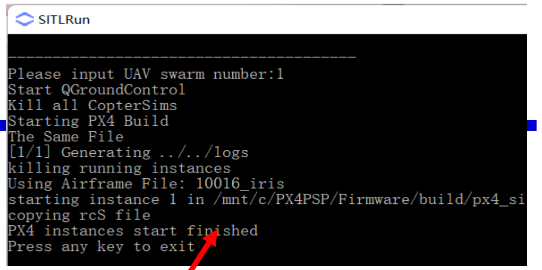
1.9 Methods for Uninstalling Platform Software

- **Automatic unloading:** Use MATLAB to open the installation package directory and run the uninstall.m script to complete the uninstallation.
- **Manual uninstall:** Includes the following process (see the notes in uninstall.m)

1. Delete the shortcut shown in RflyTools on desktop;
2. Delete the "[documents]\MATLAB\Add-Ons\Toolboxes\PX4PSP" folder.
3. Edit MATLAB "pathdef.m" to find and delete the remaining PX4PSP path entries;
4. Uninstall the Ubuntu 18.04 LTS program from Windows.
5. Delete temporary directories such as QGroundControl and FlightGear from the [Documents] directory.
6. Delete the local temporary Cesium map directory for RflyMaps.
7. Note: [document]\Ogre directory stores the serial number and other files sn6.txt, the full version will be retained.
8. Delete all files and subfolders in the installation directory (default "C:\PX4PSP") folder.

1. Platform introduction and installation





1.10 Troubleshooting Platform Installation Faults

- If blue screen, cannot be simulated, or cannot take off, please confirm the following

① f there are problems such as slow compilation, blue screen during compilation, inability to connect QGC during SITL, inability Offboard to control the aircraft, inability to connect LAN computers, etc., please confirm, please confirm to completely close or uninstall computer anti-virus software (such as Lenovo computer Butler, Tinder,360 antivirus /security guard, Tencent Computer Butler, etc.). And turn off real-time protection for Windows10!

② On the SITLRun command line interface (CLI), check whether an error message is displayed, and confirm that the px4_sitl software controller runs successfully.

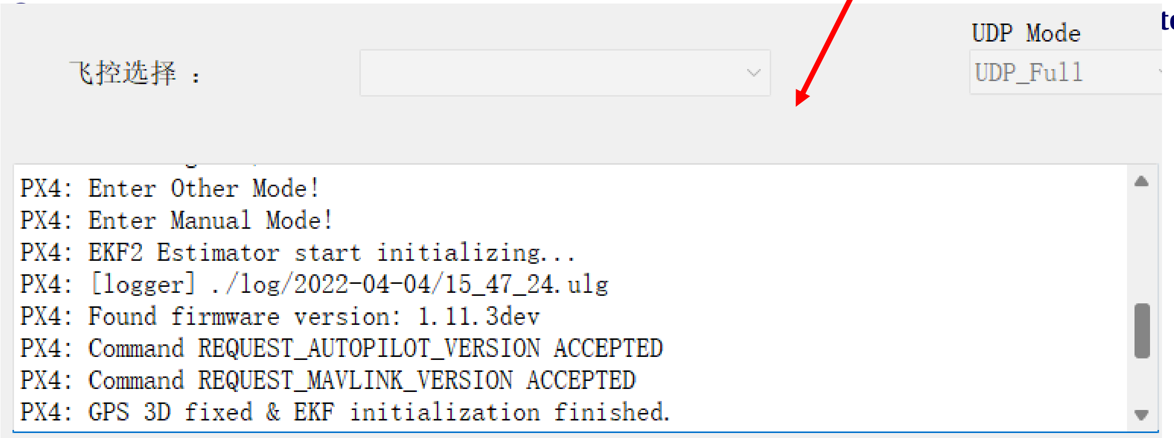
③ On the CopterSim page, the message box displays the words "3D Fixed" to ensure that the aircraft model is properly initialized and connected to the flight control.

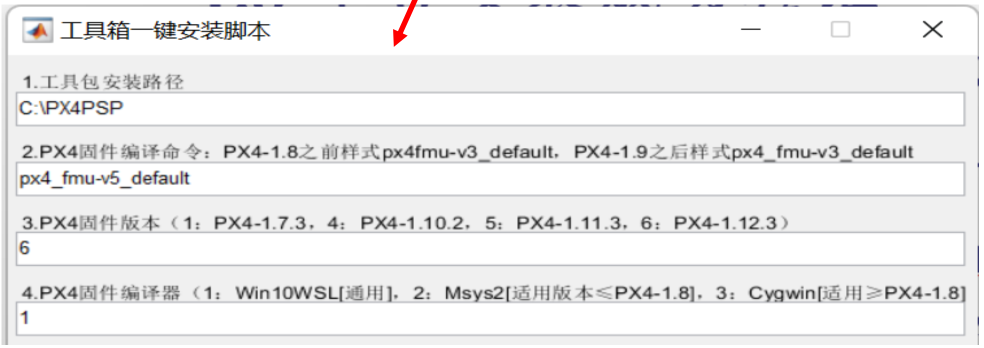
Note: You can also add antivirus exclusions according to the following text

④ Re-run the one-click installation script and go to the configuration page to confirm that the firmware version is ≥PX4 1.10 and the compiler is Win10WSL.

⑤ If still unable to take off, please post the picture and problem description on https://github.com/RflySim/Docs/issues

... to restart and re-open MATLAB to install, if not, please uninstall and reinstall.





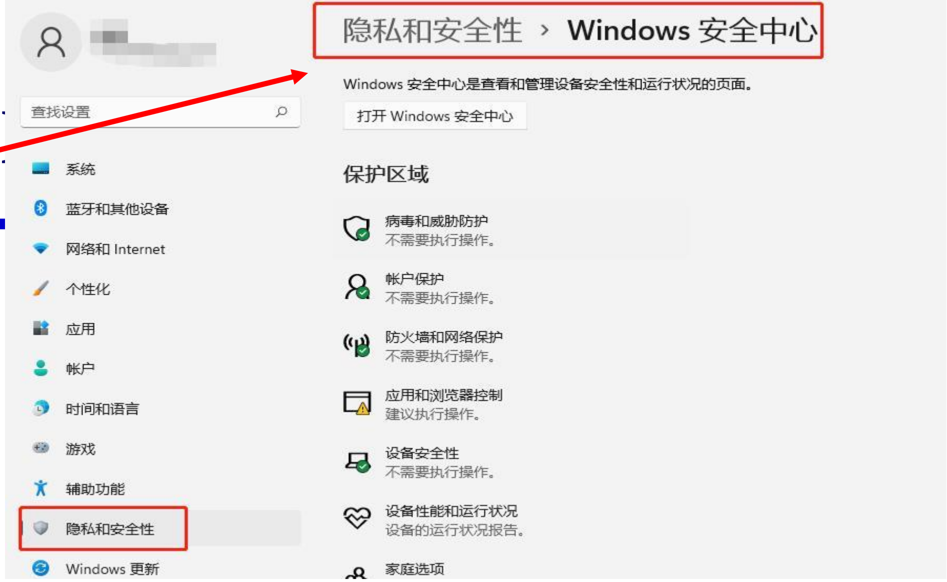
1. Platfor nd instal

Note: This step is a more convenient way than directly closing the Antivirus and Security center, and is recommended.

1.10 Platform Installation Troubleshooting -Addantivirus items.

- Click on your computer's Settings, find the Privacy and Security options, and then open Windows Security Center as shown on the right.
- Then open Virus and Threat Protection, find the administrative Settings option, and click Open.
- Then open Add or remove exclusions, click Add Folder in Add Exclusions, and add the C:\PX4PSP path (change it to the installation directory desired by the user, if you do not already have this folder, manually create a new one) to it.

Note: This step is based on Windows 11 system as an example, the operation method of other systems is similar, in addition, all anti-virus software should have the function of adding excluded folders, you can follow this step to add.



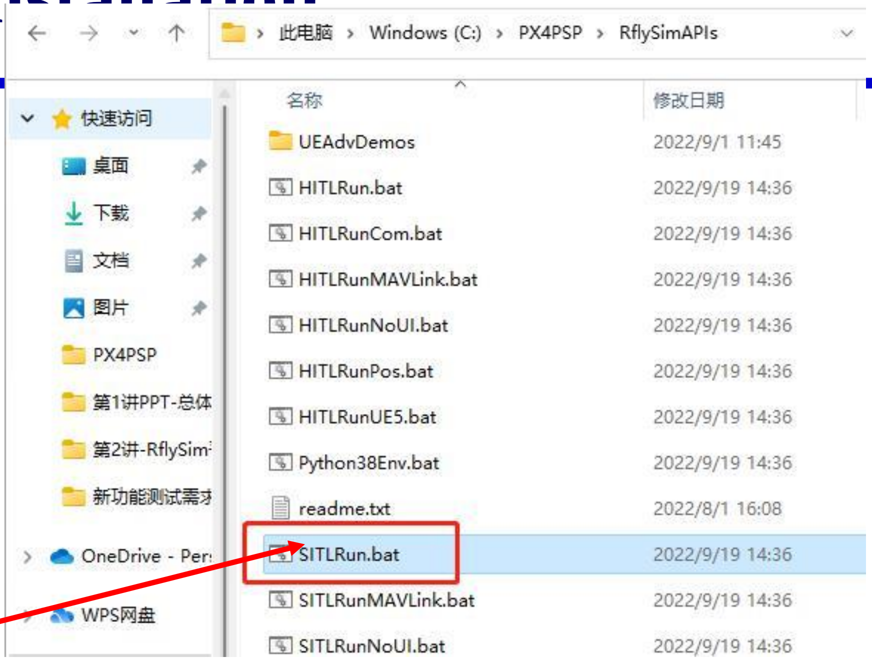
1. Platform Installation

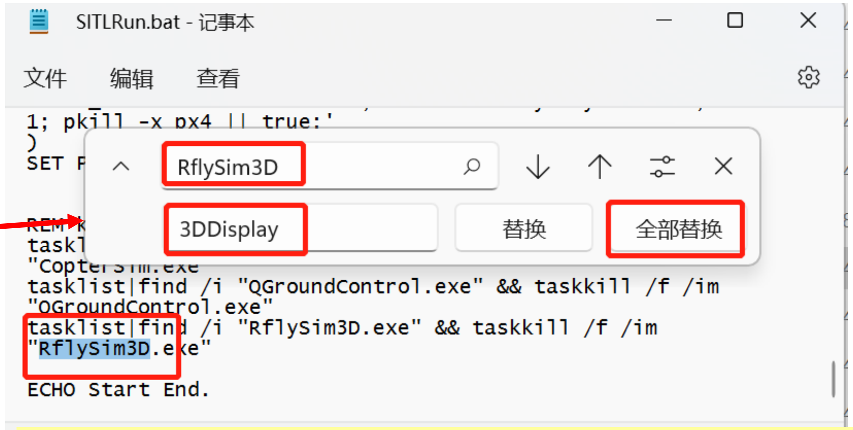
Note: The platform recommends I7+3060 and above game console configuration, and ensure power supply, other configurations may be incompatible

1.10 Troubleshooting Platform Installation - Computer configuration problems

For users with low computer configuration and flight simulation jitter, you can right-click and run the bat script in administrator mode. Second, you can modify the bat script, find and replace the RflySim3D character with 3DDisplay, and enable the simple 3D engine to observe the effect. The following uses the SITLRun script as an example:

1. Open the installation directory of the platform. The default isC:\PX4PSP\RflySimAPIs， Locate the script for SITLRun.bat.
2. Right-click edit, modify the bat script, use the replacement tool, search for and replace the BAT scriptAll RflySim3DThe character can be 3DDisplay.
3. Right-click the bat script to modify it as an administrator.





Note: 3DDisplay can only be used for single-machine pose preview.

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基础版飞控套装


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飞思实验室

RflySim教程

2. Software and hardware overview and configuration

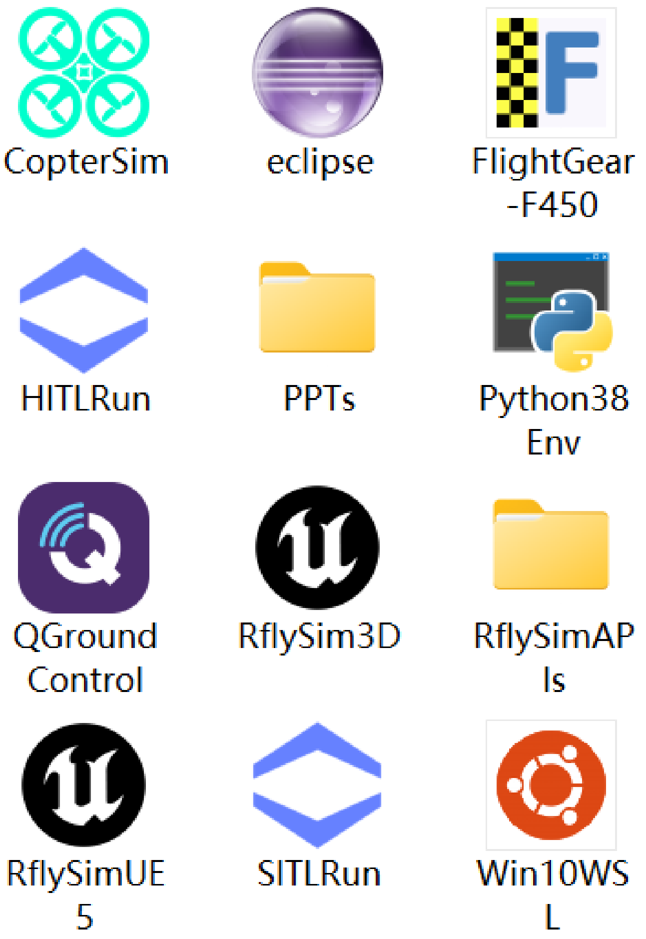
2.1 Software and Hardware Overview

- As a tool chain, the RflySim platform contains many software used in the development of unmanned systems, such as: Python 3.8 environment, MATLAB/PSP toolbox, FilghtGear, QGroundControl, etc. At the same time, the self-developed RflySim3D and CopterSim for unmanned systems.
- In addition to the software system, RflySim hardware systems include: ground computer/on-board computer, rack system, power system, remote control system, autonomous vehicle system and so on.

2. Software and hardware overview and configuration

2.2 Introduction to RflySim Core software

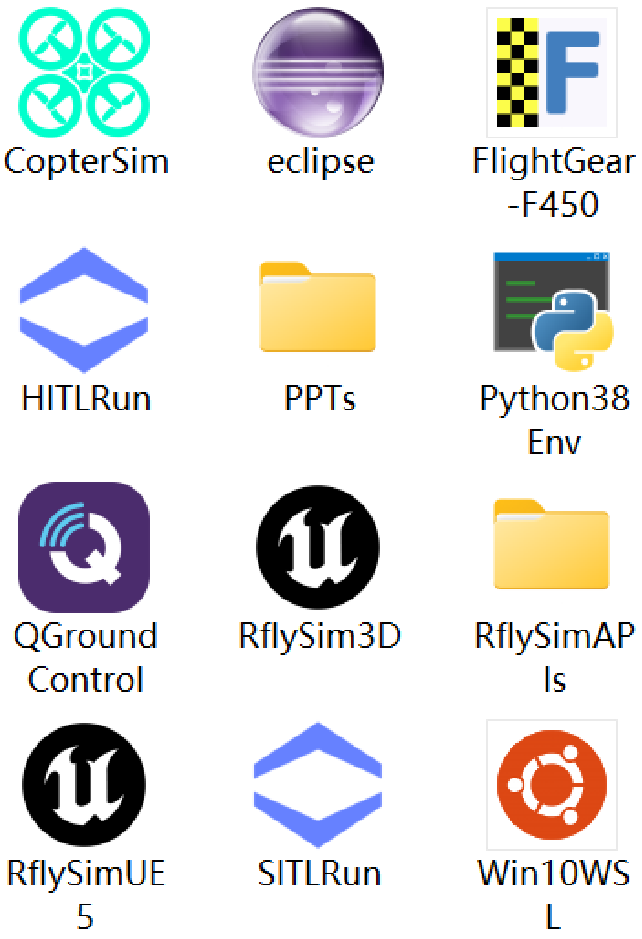
- **CopterSim:** The core simulation software of this platform runs the dynamic model of multi-rotor motion, and together with other software constitutes the software/hardware in the loop simulation.
- **RflySim3D/RflySimUE5:** The core 3D display software of this platform is based on Unreal Engine 4 (UE4, Unreal 4, full version supports UE5) engine development, with high realistic virtual reality display effect.
- **HILRun/SILRun:** The one-click quick start script enables you to quickly start all vision/cluster-related software and complete required configurations. If during the run card, a key to use HITLRunLowGPU/SITLRunLowGPU startup scripts.
- **Python38Env:** A Python environment that contains libraries such as OpenCV.
- **RflySimAPIsRoutine folder:** Contains all the routines and source code of this course, covering single/multiple aircraft control, cluster flight, visual control, etc.
- **QGroundControl（QGC）Earth station:** Includes the configuration of flight control parameters and control of aircraft take-off, landing, route and other functions. Users can read the following urls to learn how to use the software: https://docs.qgroundcontrol.com/master/en/index.html



2. Software and hardware overview and configuration

2.2 Introduction to RflySim Core software

- **Win10WSLcompiler：** Used to compile firmware and software in loop emulation.
- **Pixhawk Support Package（PSP）Toolbox：** Mathworks has officially launched a toolbox for Pixhawk autonomous vehicle, which is used to generate C code and compile and upload the control algorithm designed in Simulink to Pixhawk autonomous vehicle hardware.
- **FlightGearFlight simulator：** A very popular open source flight simulator software, it can receive the flight status sent by Simulink through UDP, and easily observe the flight status of the aircraft during Simulink simulation.
- **PX4 FirmwareFirmware source code：** PX4 is an open source flight control software system, it runs on the Pixhawk series of self-driving hardware platform, constitutes the Pixhawk PX4 self-driving hardware and software platform, is currently widely used in the world of open source UAV self-driving.
- **VS Code/Eclipse/VS：** For code reading, editing, and compiling.



2. Software and hardware overview and configuration

2.3 RflySim Core Hardware introduction

- **Ground computer/airborne computer.**
- **Rack System:** Arms, fuselage, landing gear, etc.
- **Power system:** Motor, electric regulator, battery, propeller, etc.
- **Remote control system:** Remote control transmitter, receiver, charger, lithium battery, etc.
- **Self-driving system:** Autopilot/flight control, GPS module, power module, USB data cable, data transmission module, airborne AI vision/cluster computer.
- **Dynamic capture system:** The complete dynamic capture system can be used for algorithm verification, motion planning, cluster control, human-computer interaction, trajectory playback, gait analysis, intelligent sand table, etc.

2. Software and hardware overview and configuration

2.4 Software and hardware system relationship and configuration

- In addition to software, the platform also includes hardware in the loop simulation and real machine experiment.
- The development process of low-level flight control algorithm is as follows: low-level flight control development　MATLAB software simulation　automatic code generation　flight control software simulation　flight control hardware simulation　outdoor real aircraft experiment。

2. Software and hardware overview and configuration

2.4 Software and hardware system relationsh

The functions of the one-click installation script are as follows:

① **When first installed,** Deploy the platform to the system with one click (use the default configuration and select Yes for all) and complete related configurations.

② **In subsequent use,** Run the installation script again to modify compilation commands, compilers, firmware versions, restore software, and more. (Select "No" for items that do not need to be restored, and the configuration will be updated according to the situation, saving time)

③ **After downloading the new installation package,** Run the installation script directly (select "Automatic", you will need to update the content) and click OK to start the upgrade.

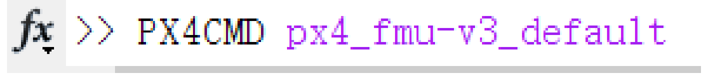
2. Software and hardware overview and configuration

One-click installation script options detailed:

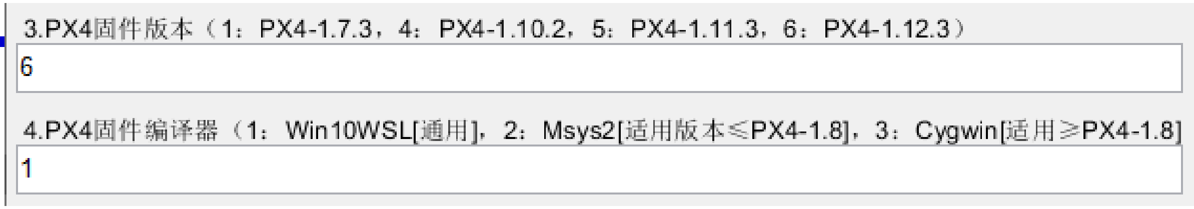
1）**Tool package installation path**. All the dependent files of this platform will be installed in this path, which requires about 20G of space. The default installation path is C:\PX4PSP. If the C drive space is insufficient, you can choose another drive. Note: The path name must be correct, and only the pure English path, otherwise the compilation will fail.

2） PX4 firmware compilation command.It mainly corresponds to the development needs of the underlying controller, and uses the code generation function, which needs to select the compilation command according to the flight control hardware(Note: Top-level vision and cluster algorithm development users do not need to configure, keep the default) .The default value droneyee_zyfc-h7_default corresponds to the Drow H7 autopilot. In addition, the platform will support the following three flight controls for a long time: Pixhawk V6X compilation command: px4_fmu-v6x_default; The Pixhawk V6C compilation command is px4_fmu-v6c_default; The Pixhawk 1 compilation command is px4_fmu-v3_default. For more flight control compilation instructions, see:https://doc.rflysim.com/hardware.html。

Note: In addition to re-running this installation script after the first installation is complete, another way to change the compilation command for different Pixhawk hardware boards (for example, to px4_fmu-v3_default) is to enter the command in MATLAB: PX4CMD(' px4_fmu-v3_default') or use the command: PX4CMD px4_fmu-v3_default



2. Software and hardware overview and configuration



One-click installation script options detailed

3）PX4 Firmware version.The PX4 source code is updated every year, and the latest firmware version is currently 1.12. As the firmware version is upgraded, the features will gradually increase and the more new products are supported, but the compatibility with some of the older self-driving hardware will become worse. This experiment course recommends the use of Zhuoyi H7 flight control, corresponding to the compilation command "droneyee_zyfc-h7_default", the selected firmware versionPX4-1.12.3。

4）PX4 Firmware compiler.Since the compilation of PX4 source code depends on the Linux compilation environment and related components, this platform provides three sets of compilation environments to achieve the simulation of Linux compilation environment under the Windows platform, they are: Win10WSL compiler based on Windows Subsystem for Linux (WSL), Msys2Toolchain compiler based on Msys2 and CygwinToolchain compiler based on Cygwin. Note that if you want to compile firmware ≥PX4-1.8, you need to select the CygwinToolchain compiler. To compile firmware versions ≤PX4-1.8, select the Msys2Toolchain compiler. Native compilers based on Msys2 or Cygwin, supporting WIndows 7-11 platforms, and easy to deploy, but low compilation efficiency. For Windows 101809 and above system versions, it is recommended to install Win10WSL compiler, this way can greatly speed up the compilation speed, and compatible with all versions of PX4 flight control firmware.

2. Software and hardware overvi

One-click installation script options detailed

5）Whether to install the PSP toolkit. If this option is set to Yes, the PSP toolbox will be installed in the local MATLAB software. If the PSP toolbox has already been installed, a fresh installation of the PSP toolbox is performed. If No is selected, the script does not make any changes to the PSP toolbox (it does not uninstall the installed PSP toolbox or other actions).

6）Whether to install other dependency packages from scratch. If this option is set to Yes, software such as QGC Ground Station, CopterSim, 3DDisplay, etc. will be deployed on the set installation path, along with the related drivers for Pixhawk hardware, and shortcuts to these software will be generated on the desktop. If the dependent software has been deployed in the installation path, select Yes to delete the old installation package and reinstall it. If this option is set to No, no changes are made.

7）Whether to configure a new firmware compiler compilation environment. If this option is set to Yes, the selected compiler (Win10WSL, CygwinToolchain, or Msys2Toolchain) will be deployed on the set installation path, and if the environment already exists, the old compilation environment will be cleared for restoration and new deployment. Conversely, if this option is set to No, no changes are made.

Note: You can also specify the name (comma separated) of the individual app you want to reinstall directly in (6). Available options include:CopterSim,drivers,FlightGear,QGroundControl,RflySim3D,RflySimAPIs,UE 3DDisplay

2. Software and hardware overview and configuration

One-click installation script options detailed

8）Whether to deploy the PX4 firmware code. If this option is set to "Yes", the selected PX4 Firmware source code is deployed on the set installation path, and if the firmware exists, the old firmware folder is deleted and a new deployment is performed. If this option is set to No, no changes will be made.

9）Whether the firmware is newly compiled. If this parameter is set to "Yes", the deployment firmware is precompiled, which greatly reduces the time of subsequent code generation and compilation, and enables you to check whether the environment installation is normal. If this option is set to No, no changes will be made.

10）Whether to mask the output of the PX4 controller. If this option is set to "Yes", the Firmware's control signals to the motor are masked to prevent conflicts with the generated code (Note: This option does not mask the output of the PX4_SITL controller, so software-in-the-loop simulation can be performed normally). If you select "No", the firmware output will not be masked, and it can be used to test the control algorithm of the PX4. Therefore, if you want to generate official firmware, please select "No" for this option.

2. Software and hardware overvie

2.5 Introduction to model-based development process

(1) The software is in the ring simulation stage

The whole stage is carried out in the MATLAB environment, using the given multi-rotor simulation model and routine, the control algorithm is designed in Simulink, and the model and controller are correctly connected to ensure that the input and output signals are consistent with the actual multi-rotor system. Similar to a real multi-rotor system, the multi-rotor model sends sensor data or state estimation information (e.g., attitude Angle, angular rate, position, and speed, etc.) to the controller, which sends each motor PWM control command back to the model, resulting in a software-in-the-loop simulation closed-loop system. In this phase, the reader can observe the control performance and modify or design the controller to meet the desired performance requirements.

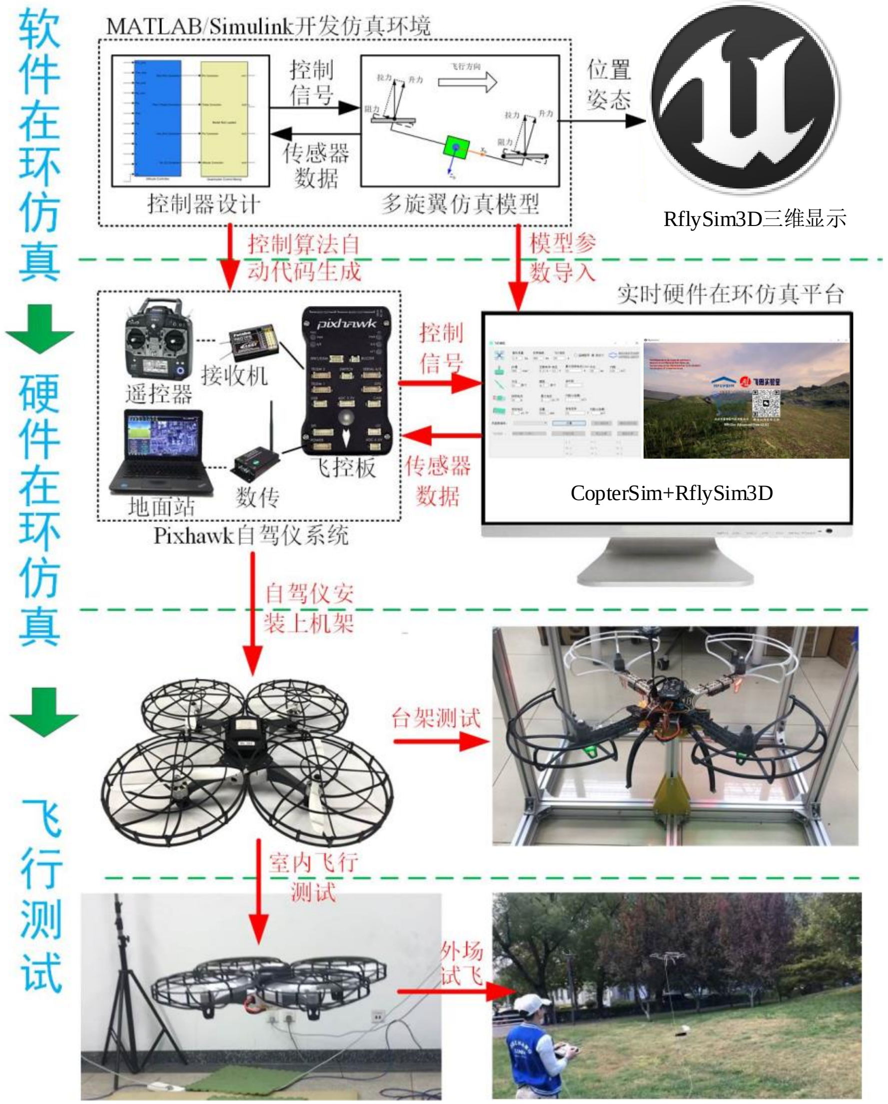


Diagram. Experimental flow chart

2. Software and hardware overview and configuration

2.5 Introduction to model-based development process

(2) Hardware in the ring simulation stage

Experiment with a given model and routine. The model is built in a hardware-in-the-loop multi-rotor vehicle simulator, and the controller is uploaded to the Pixhawk flight control hardware environment, where the communication process is directly connected via a serial cable. The model sends the attitude Angle, attitude Angle rate, position and speed to the controller through the serial port line, and the controller sends each motor PWM control command back to the model through the serial port line, thus forming a closed loop.

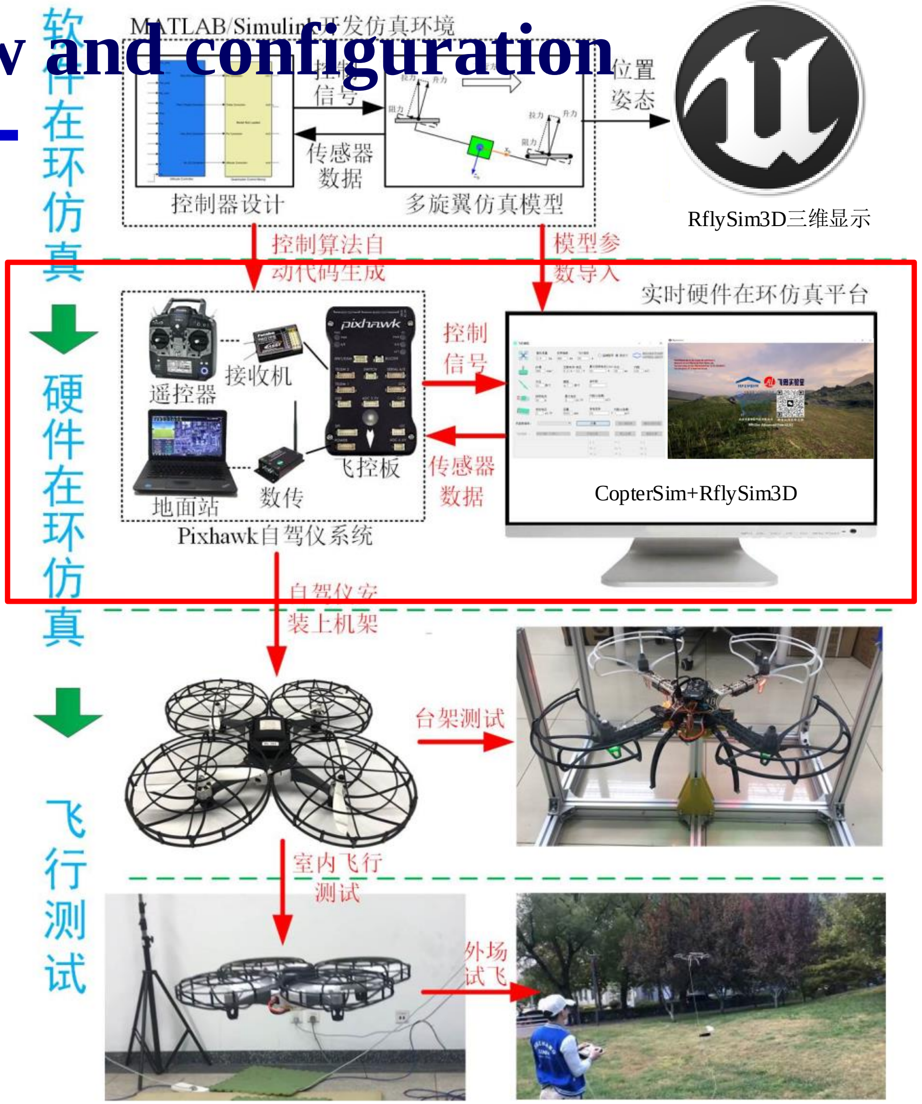


Diagram. Experimental flow chart

2. Software and hardware overview and configuration

2.5 Introduction to model-based development process

(2) Hardware in the ring simulation stage

The Simulink multi-rotor model parameters were imported into CopterSim, and the Simulink controller algorithm generated code was downloaded to the Pixhawk self-driving device, and then the virtual signal line in Simulink was replaced with a USB physical signal cable. CopterSim sends sensor data (e.g., accelerometers, barometers, magnetometers, etc.) to the Pixhawk system via a USB cable; The PX4 autopilot software in Pixhawk system will receive sensor data for filtering and state estimation, and send the estimated state information to the controller through the internal uORB message bus. The controller then sends PWM control instructions of each motor back to CopterSim via USB data cable, thus forming a hardware-in-the-loop simulation closed loop.

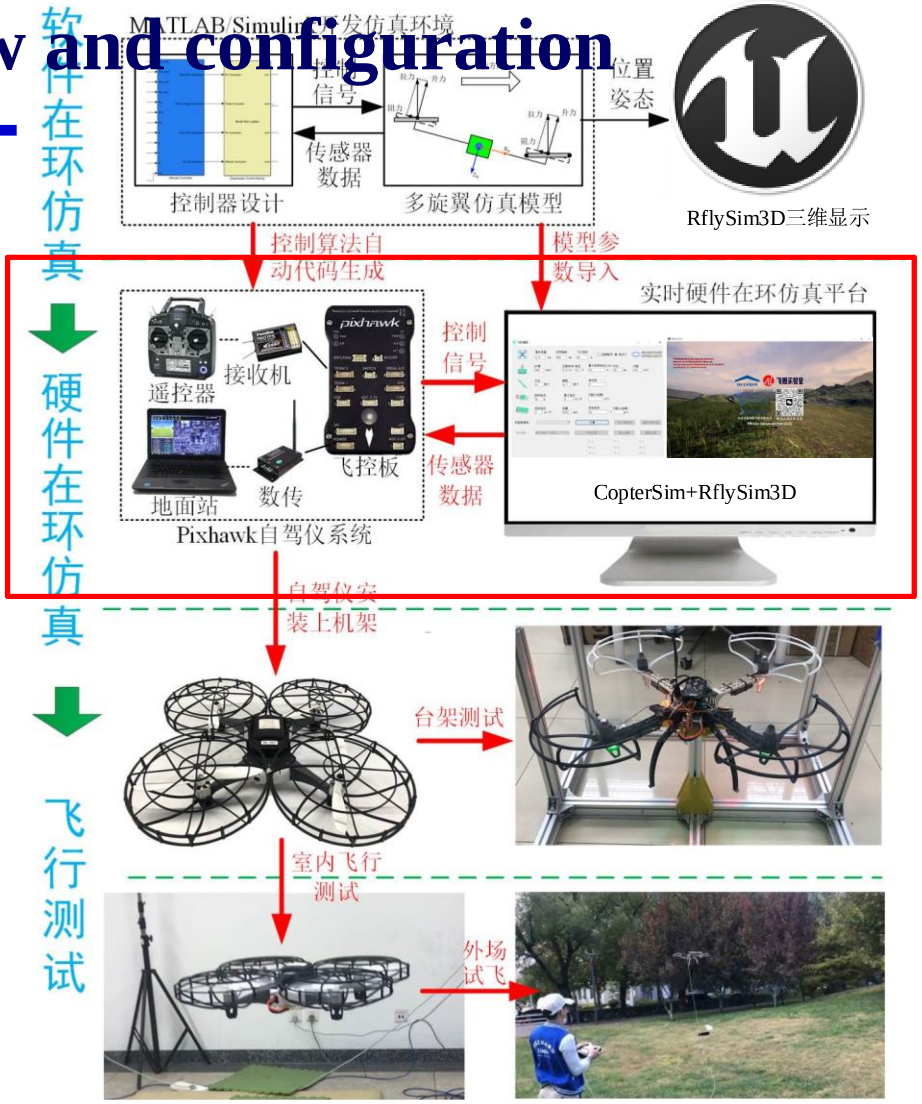


Diagram. Experimental flow chart

2. Software and hardware overview and configuration

2.5 Introduction to model-based development process

(2) Hardware in the ring simulation stage

Compared with software-in-the-loop simulation, the running speed of the multi-rotor model in the hardware-in-the-loop simulation is consistent with the actual clock, so as to ensure the real-time performance of the simulation. Meanwhile, the control algorithm can be deployed and run in the real embedded system, which is closer to the actual multi-rotor system. It should be noted that there may be transmission delay in the actual hardware communication, and the simulation model of the hardware in the ring system and the operating environment of the controller are inevitably different from that of the software in the ring system. Therefore, the parameters of the controller may need to be further adjusted to meet the design requirements, which precisely reflects the actual situation.

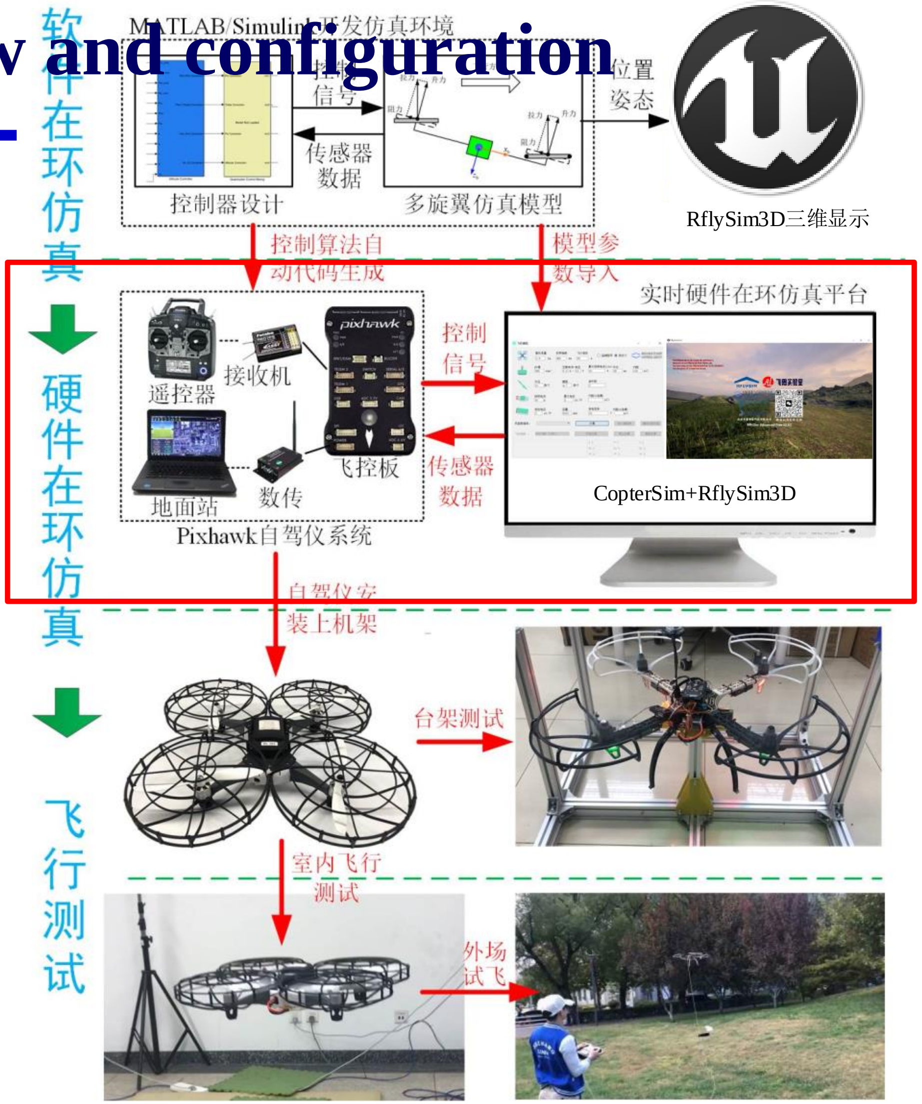


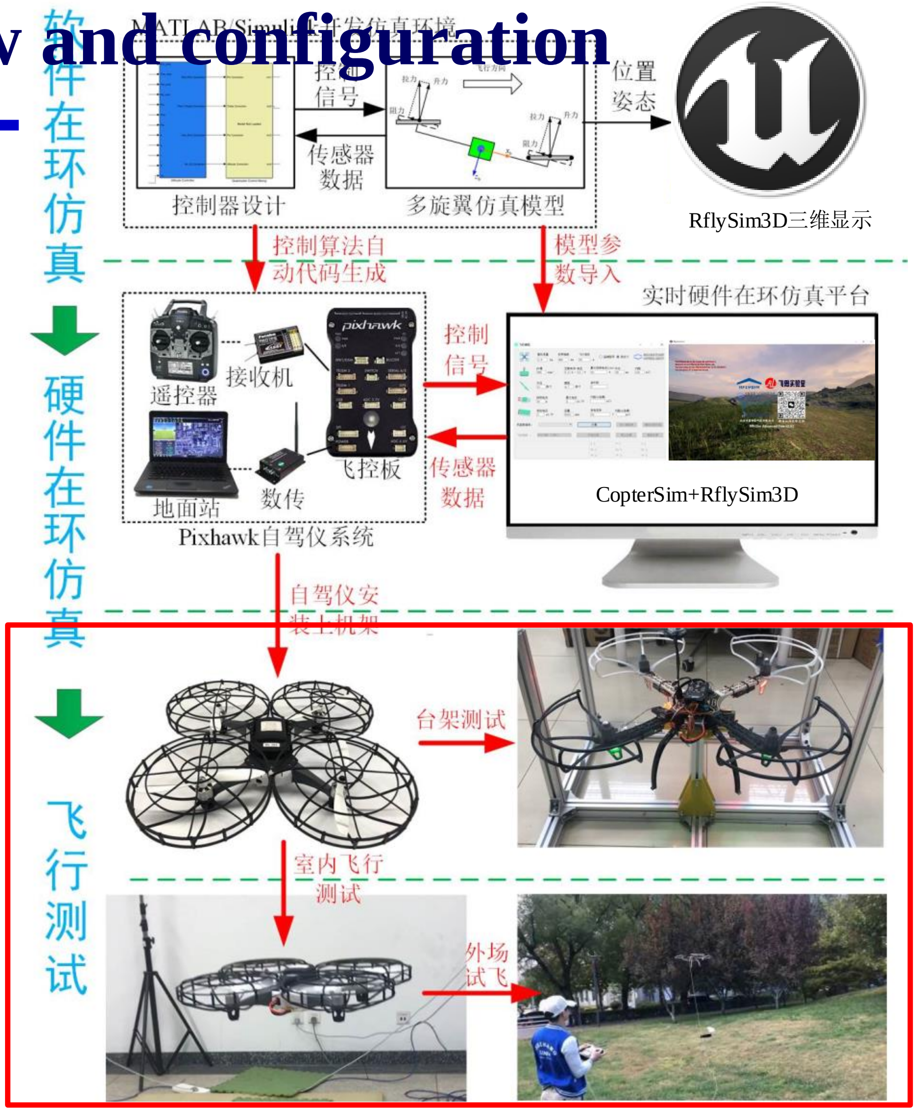
Diagram. Experimental flow chart

2. Software and hardware overview and configuration

2.5 Introduction to model-based development process

(3) Flight test phase

At this stage, the virtual simulation model of CopterSim is further replaced by the real multi-rotor aircraft, the sensor data is directly obtained by the sensor chip to sense the flight motion state, and the controller signal is directly output to the motor, so as to realize the control of the real aircraft. It should be noted that both hardware-in-the-loop simulation and software-in-the-loop simulation models are difficult to be completely consistent with real aircraft, so further parameter adjustment is necessary.



outline

1. Platform introduction and installation
2. Software and hardware overview and configuration
3. Soft and hard basic use experiment
5. Experimental preview in the following chapters
6. Future functions and prospects
7. Summarize

To purchase the teaching AIDS required for this course (already configured and ready to use, you can skip the hardware configuration part of this PPT), you can visit the following Taobao store link or scan the QR code on the right side of Taobao App https://shop212206553.taobao.com/

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基础版飞控套装

高级版飞控套装

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RflySim教程

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3.1 CopterSim use experiment

This experiment can solve the UAV dynamic system model after CopterSim is set up. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\ e1_CopterSim-Usage", the specific experimental operation see the file:1.BasicExps\e1_CopterSim-Usage\Readme.pdf , The experimental effects are as follows (part) :

3. Soft and hard basic use experiment

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3.2 CopterSim Import DLL experiment

In this experiment, a fixed wing model of Simulink was provided, which was exported as DLL file with one click, then loaded into CopterSim, and finally simulated. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e2_DLL-Load", the specific experimental operation see the file 1.BasicExps\e2_DLL-Load\Readme.pdf , The experimental results are as follows (part) :

3. Soft and hard basic use experiment

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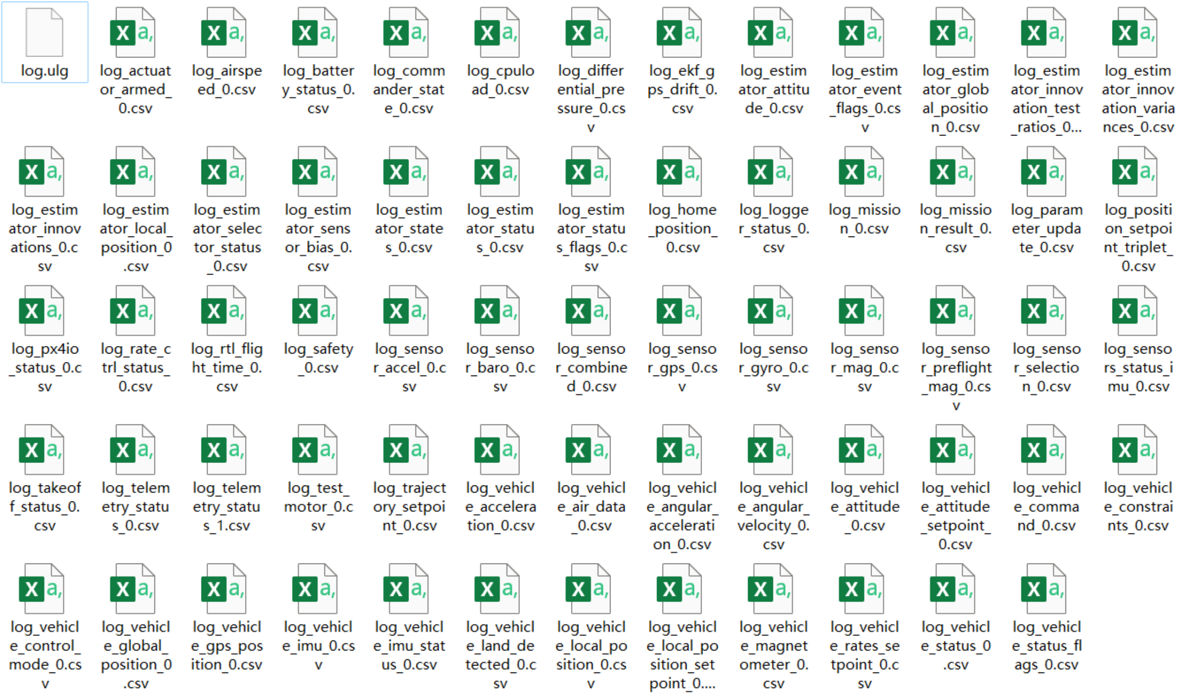
3.3 RflySim3D shortcut key and command experiment

This experiment mainly explains the basic operation of RflySim3D, the use of shortcut keys and shortcut commands. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e3_RflySim3D-Shortcut-Instruct", specific experiment operations see the file 1.BasicExps\e3_RflySim3D-Shortcut-Instruct\Readme.pdf **, The experimental effects are as follows (part) :**

3. Soft and hard basic use experiment

3.4 Python38Env read flight log experiment

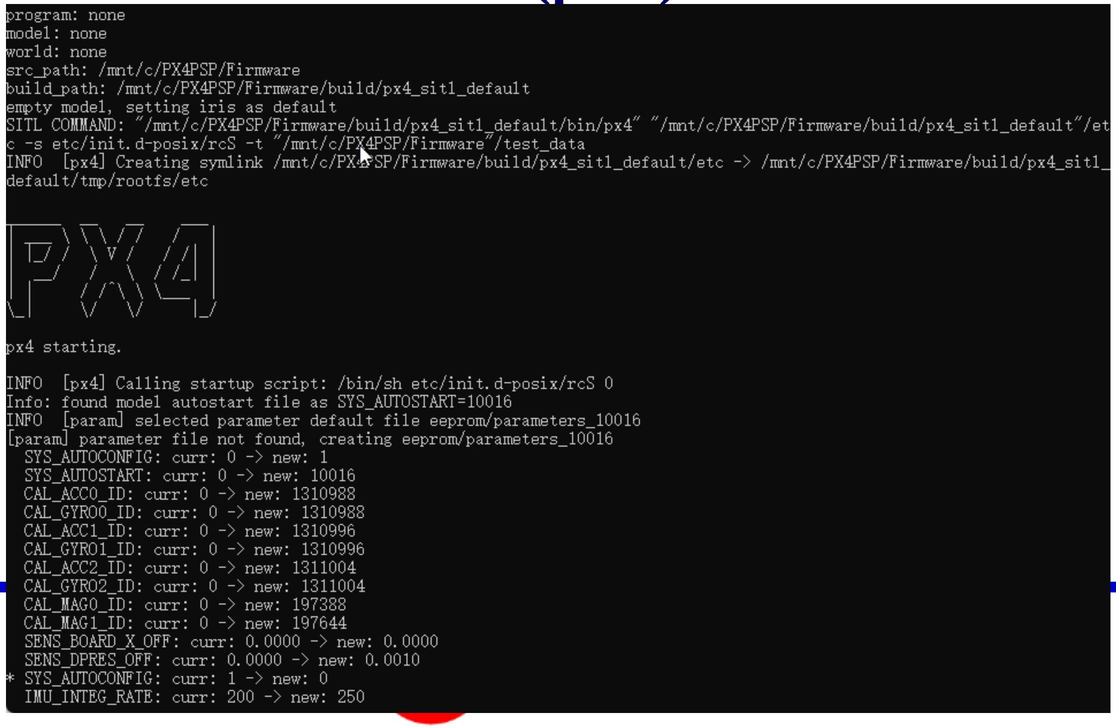
This experiment is based on Python3.8 environment to read the flight log.ulg file. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e4_Log-Reads-Python38Env", the specific experimental operation see the file 1.BasicExps\e4_Log-Reads-Python38Env\Readme.pdf , The experimental results are as follows (part) :



3. Soft and hard basic use experiment

3.5 Manual software in the loop simulation configuration experiment

This experiment is based on Win10WSL compiling simulation instructions to realize manual configuration of the whole software in the loop simulation environment. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e5_Manual-SIL", the specific experimental operation see the file1.BasicExps\e5_Manual-SIL\Readme.pdf ,
The experimental results are as follows (part) :



3. Soft and hard basic use experiment

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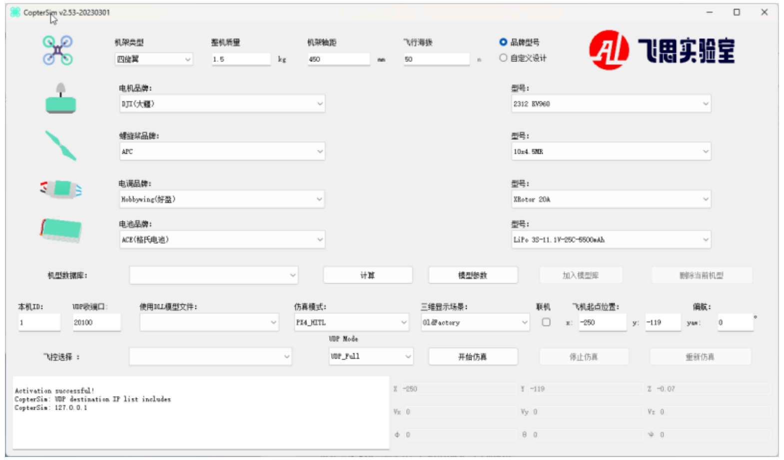
3.6 BAT Script to Start Component Experiments

This experiment is based on Windows batch processing language, writing BAT script to realize the one-click of multiple components in RflySim. Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e6_BAT-Startup", the specific experimental operation see the file 1.BasicExps\e6_BAT-Startup\Readme.pdf , The experimental results are as follows (part) :



3. Soft and hard basic use experiment

3.7 MATLAB code automatic generation flight control firmware experiment

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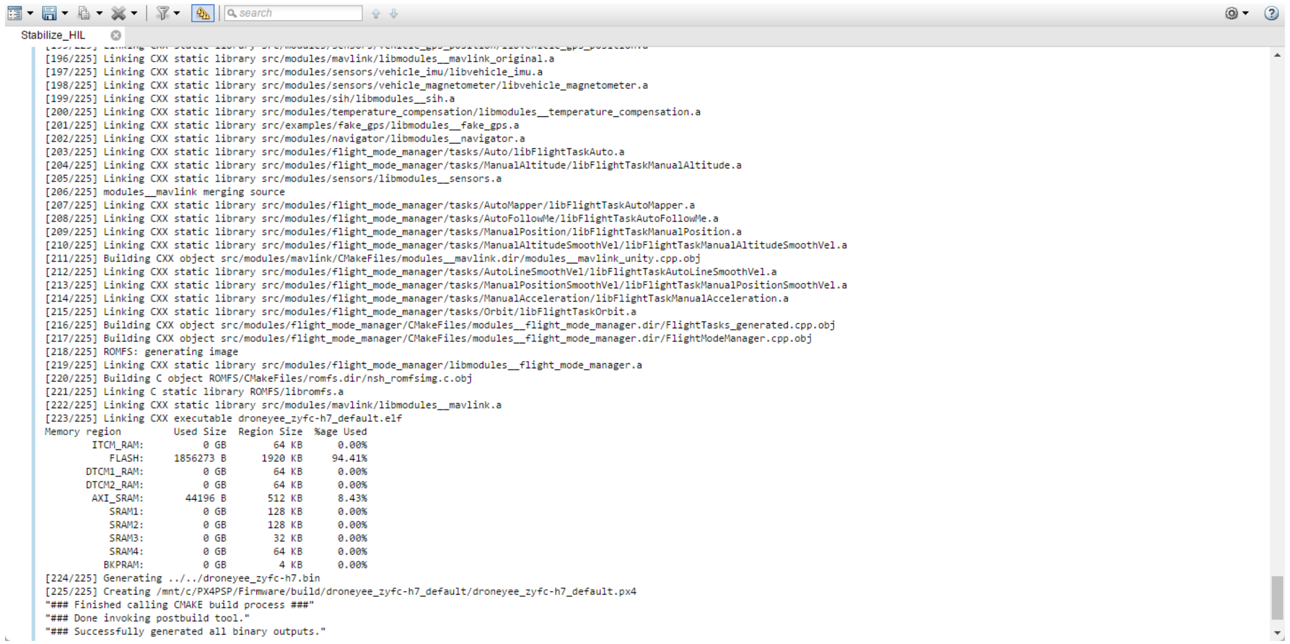
watch this experiment video tutoria

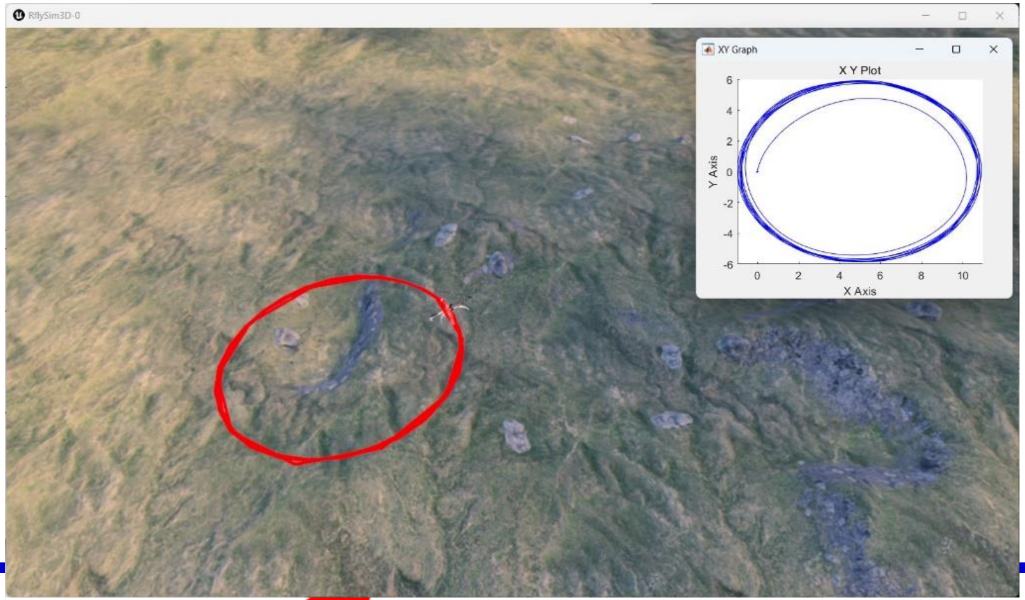
This experiment is based on the MATLAB automatic code generation module of RflySim platform, and the control model built in Simulink can directly generate flight control firmware with one click. See the document for detailed experimental operation1.BasicExps\e7_Code-Generation\Readme.pdf, The experimental results are as follows (part) :



3. Soft and hard basic use experiment

3.8 Simulink Cluster Control Interface

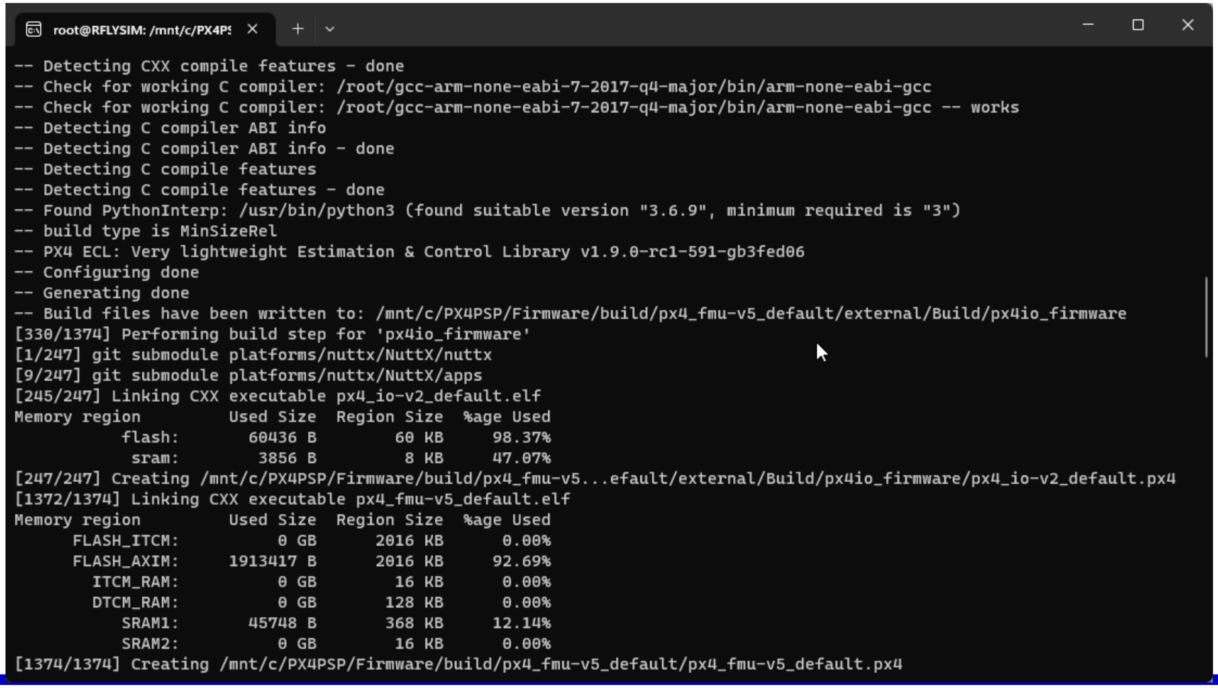
By running the bat script in this routine folder, you can start QGC, CopterSim and RflySim3D software with one click. After running Simulink, you can see the drone take off and enter the hovering state. See the document for detailed experimental operation1.BasicExps\e8_SwarmAPI\Readme.pdf, Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e8_SwarmAPI", the experimental effect is as follows (part) :



3. Soft and hard basic use experiment

3.9 PX4 Firmware compilation

In this experiment, the PX4 firmware is compiled by Win10WSL. See the document for detailed experimental operation1.BasicExps\e9_Build-Firmware\Readme.pdf, Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e9_Build-Firmware", the experimental effect is as follows (part) :



3. Soft and hard basic use experiment

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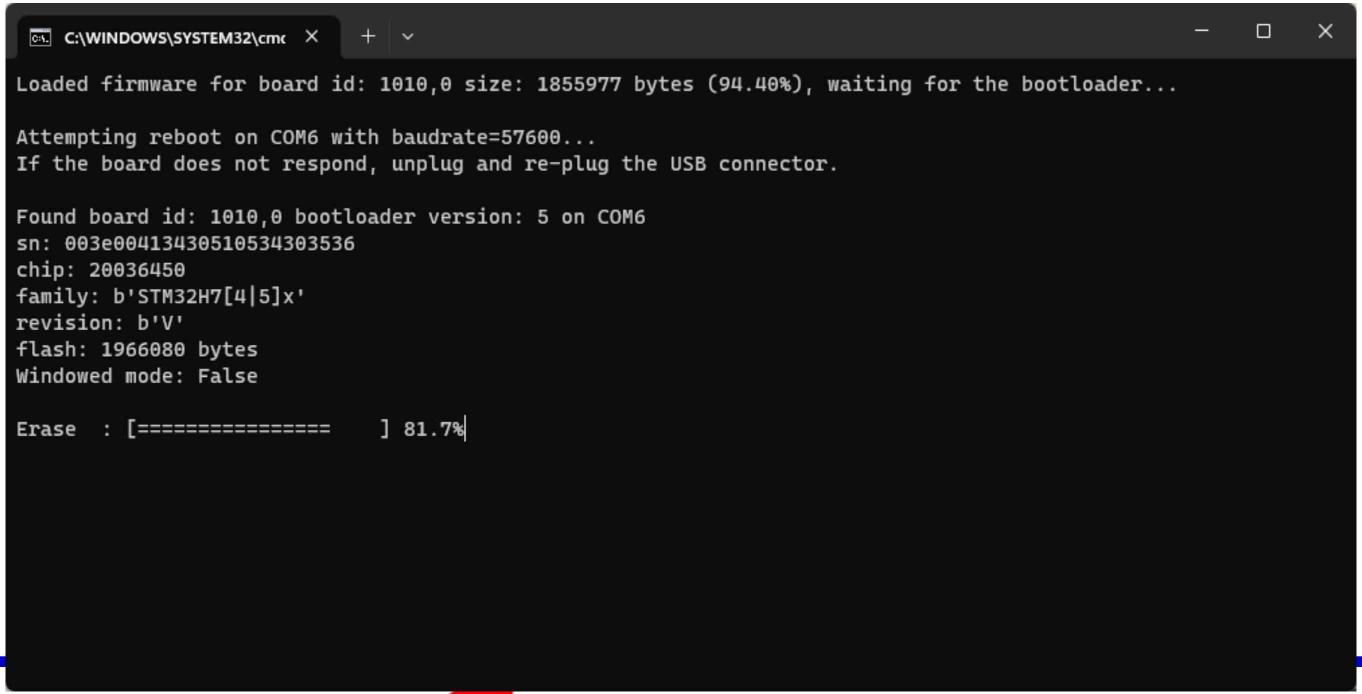
3.10 Flight control firmware burning experiment

This experiment introduces two different firmware burning methods of RflySim platform. Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e10_Firmware-Upload", the specific experimental operation see the file 1.BasicExps\e10_Firmware-Upload\Readme.pdf， The experimental effects are as follows (part) :



飞思实验室

3. Soft and hard basic use experiment

3.11 Remote control configuration experiment

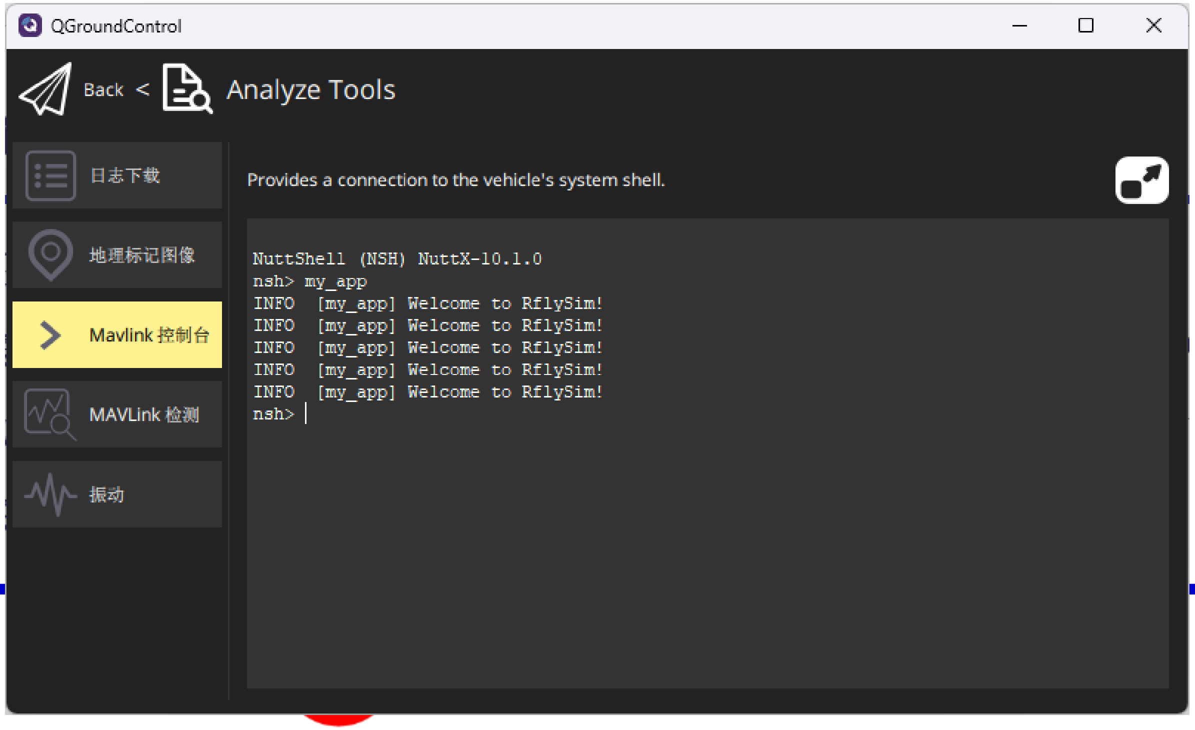
The remote control used in this platform is recommended to use the "American hand" control mode, that is, the left rocker corresponds to the throttle and yaw control amount, while the right rocker corresponds to the roll and pitch. Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e11_RC-Config", the specific experimental operation see the file1.BasicExps\e11_RC-Config\Readme.pdf， Use the remote control configuration manual and other materials in this routine folder to configure your remote control.

油门：控制上下运动，对应固定翼油门杆
偏航：控制机头转向，对应固定翼方向舵
俯仰：控制前后运动，对应固定翼升降舵
滚转：控制左右运动，对应固定翼副翼

3. Soft and hard basic use experiment

3.12 Flight control onboard application development experiment

This experiment focuses on how to create and run your first onboard application and master all the basic concepts and apis needed for PX4 application development. Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e12_PX4-App", the specific experimental operation see the file1.BasicExps\e12_PX4-App\Readme.pdf， The experimental results are as follows (part) :



3. Soft and hard basic use experiment

3.13 Quadrotor UAV configuration experiment

This experiment introduces the composition structure and simple configuration of Feisi X450 UAV platform. Folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e13_UAV-Config", the specific experimental operation see the file1.BasicExps\e13_UAV-Config\Readme.pdf， The experimental results are as follows (part):

飞思X450飞行器	
尺寸	折叠尺寸：760*760*220mm
对称电机轴距	455mm
机体重量（不含电池）	1134g
最大载重	1800g
机体材料	碳纤维、尼龙
通讯接口	WiFi
电池	6s-9000mAh，0.934kg
定位系统下悬停精度	垂直：±0.05m；水平：±0.05m
最大上升速度	2m/s
最大下降速度	2m/s
最大水平飞行速度	10m/s
最大起飞海拔高度	5000m
续航时间（空载）	38分钟
工作环境温度	-20° C至 50° C
基本配置	光流传感器、激光定高传感器、独立外磁
机载板卡	NX 、nano
可选载荷配置	CSI相机、T265、D435iS1激光雷达
通讯板卡	rockpi、nx板卡、数传、nanopi、4G模块、 RTK

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3. Soft and hard basic use experiment

3.14 CopterSim Obtain Log Data Experiment

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In this experiment, CopterSim was used to record the data obtained in the simulation process. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e14_Log-Get", the specific experimental operation see the file1.BasicExps\e14_Log-Get\Readme.pdf,The experimental results are as follows (part) :

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	0:runnedTi	1:copterID	2:vehicleTy	3:PosE[0]-)	4:PosE[1]-'	5:PosE[2]-/	6:VelE[0]-\	7:VelE[1]-\	8:VelE[2]-\	9:AngEuler	10:AngEule	11:AngEule	12:RateB[0	13:RateB[1	14:RateB[2	15:AccB[0]	16:AccB[1]	17:AccB[2]	18:AngQua
6313	126.95	1	3	-0.01409	-0.02045	-17.9733	0.02944	-0.00075	-0.03262	0.001824	0.000258	-5.46E-05	-0.00959	0.009689	-0.00039	1	0.000912	0.000129	-2.74E-05
6314	126.965	1	3	-0.01365	-0.02046	-17.9738	0.029391	-0.0005	-0.0324	0.001668	0.0004	-6.10E-05	-0.01127	0.009523	-0.00051	1	0.000834	0.0002	-3.07E-05
6315	126.99	1	3	-0.01291	-0.02047	-17.9746	0.029261	-0.00012	-0.03201	0.001372	0.000663	-7.78E-05	-0.01147	0.011485	-0.00089	1	0.000686	0.000332	-3.91E-05
6316	127.01	1	3	-0.01233	-0.02047	-17.9753	0.029107	0.000124	-0.03171	0.00116	0.000907	-9.94E-05	-0.00924	0.012849	-0.00129	1	0.00058	0.000453	-4.99E-05
6317	127.025	1	3	-0.01189	-0.02047	-17.9757	0.028959	0.000285	-0.03151	0.001046	0.001101	-0.00012	-0.00594	0.01276	-0.00152	1	0.000523	0.00055	-6.05E-05
6318	127.05	1	3	-0.01117	-0.02046	-17.9765	0.028649	0.00053	-0.03124	0.000991	0.001429	-0.00016	0.001749	0.014005	-0.00186	1	0.000495	0.000714	-8.15E-05
6319	127.07	1	3	-0.0106	-0.02045	-17.9771	0.028341	0.000732	-0.03111	0.001083	0.001709	-0.0002	0.007422	0.013359	-0.00202	0.999999	0.000542	0.000855	-0.0001
6320	127.085	1	3	-0.01018	-0.02043	-17.9776	0.028075	0.000901	-0.03106	0.001225	0.001898	-0.00023	0.011327	0.012173	-0.00208	0.999999	0.000612	0.000949	-0.00012
6321	127.11	1	3	-0.00948	-0.02041	-17.9784	0.027572	0.00124	-0.03103	0.00156	0.002201	-0.00028	0.014897	0.011584	-0.00224	0.999999	0.00078	0.0011	-0.00014
6322	127.125	1	3	-0.00907	-0.02039	-17.9789	0.027236	0.001486	-0.03105	0.001788	0.002359	-0.00032	0.015036	0.009416	-0.00228	0.999999	0.000894	0.001179	-0.00016
6323	127.15	1	3	-0.0084	-0.02034	-17.9796	0.026631	0.001968	-0.03114	0.002121	0.002553	-0.00037	0.011143	0.005936	-0.00225	0.999999	0.001061	0.001276	-0.00019
6324	127.165	1	3	-0.008	-0.02031	-17.9801	0.02625	0.002291	-0.03119	0.002266	0.002624	-0.00041	0.008317	0.003571	-0.00224	0.999998	0.001133	0.001312	-0.00021
6325	127.19	1	3	-0.00735	-0.02025	-17.9809	0.025598	0.002868	-0.03119	0.002424	0.002691	-0.00046	0.003691	0.002198	-0.00217	0.999998	0.001212	0.001345	-0.00023
6326	127.205	1	3	-0.00697	-0.0202	-17.9813	0.0252	0.003227	-0.03115	0.002456	0.002717	-0.0005	0.000865	0.001343	-0.00208	0.999998	0.001229	0.001358	-0.00025
6327	127.23	1	3	-0.00635	-0.02011	-17.9821	0.02453	0.003828	-0.03095	0.002436	0.002748	-0.00054	-0.00239	0.001158	-0.00186	0.999998	0.001219	0.001374	-0.00027
6328	127.25	1	3	-0.00587	-0.02003	-17.9827	0.023991	0.004299	-0.03062	0.002373	0.002755	-0.00058	-0.00356	-0.00101	-0.00161	0.999998	0.001187	0.001377	-0.00029
6329	127.27	1	3	-0.00539	-0.01994	-17.9833	0.023456	0.004756	-0.03017	0.002304	0.002711	-0.00061	-0.00282	-0.00278	-0.00138	0.999998	0.001152	0.001355	-0.00031
6330	127.29	1	3	-0.00493	-0.01984	-17.9839	0.022931	0.005202	-0.02961	0.002262	0.002651	-0.00063	-0.00132	-0.0036	-0.00112	0.999998	0.001131	0.001325	-0.00032
6331	127.31	1	3	-0.00447	-0.01973	-17.9845	0.02242	0.005643	-0.02895	0.002247	0.002585	-0.00066	-0.00022	-0.00281	-0.00088	0.999998	0.001124	0.001292	-0.00033
6332	127.325	1	3	-0.00414	-0.01965	-17.985	0.022044	0.005972	-0.02841	0.002245	0.002546	-0.00067	-0.00026	-0.00235	-0.00075	0.999999	0.001123	0.001273	-0.00034
6333	127.345	1	3	-0.00371	-0.01952	-17.9855	0.02155	0.00641	-0.02768	0.002232	0.002515	-0.00068	-0.0011	-0.00049	-0.00067	0.999999	0.001117	0.001257	-0.00034
6334	127.37	1	3	-0.00317	-0.01935	-17.9862	0.020934	0.00695	-0.02677	0.00219	0.002544	-0.0007	-0.00211	0.002964	-0.00055	0.999999	0.001095	0.001271	-0.00035
6335	127.39	1	3	-0.00276	-0.01921	-17.9867	0.020431	0.007374	-0.02608	0.00214	0.002609	-0.00071	-0.00278	0.002937	-0.00041	0.999999	0.00107	0.001304	-0.00035
6336	127.41	1	3	-0.00236	-0.01906	-17.9872	0.019917	0.007786	-0.02544	0.002073	0.002639	-0.00071	-0.00415	-5.35E-05	-0.00025	0.999999	0.001037	0.001319	-0.00036
6337	127.425	1	3	-0.00206	-0.01894	-17.9876	0.019531	0.008085	-0.025	0.002008	0.002618	-0.00072	-0.00433	-0.00319	-0.00019	0.999999	0.001004	0.001309	-0.00036
6338	127.445	1	3	-0.00168	-0.01878	-17.9881	0.01903	0.00847	-0.02448	0.001932	0.002493	-0.00072	-0.00297	-0.0087	-0.00015	0.999999	0.000966	0.001246	-0.00036
6339	127.47	1	3	-0.00121	-0.01856	-17.9887	0.018449	0.008937	-0.02393	0.001895	0.002251	-0.00072	-6.63E-05	-0.01003	-7.93E-05	0.999999	0.000948	0.001125	-0.00036
6340	127.49	1	3	-0.00084	-0.01838	-17.9892	0.018028	0.009308	-0.02349	0.001908	0.002066	-0.00072	0.001038	-0.00776	8.01E-05	0.999999	0.000954	0.001033	-0.00036
6341	127.51	1	3	-0.00049	-0.01819	-17.9897	0.017637	0.009683	-0.02301	0.001917	0.001947	-0.00072	-0.00011	-0.00437	0.000247	0.999999	0.000959	0.000973	-0.00036
6342	127.53	1	3	-0.00014	-0.01799	-17.9901	0.017262	0.010057	-0.02248	0.001904	0.001898	-0.00071	-0.00149	-0.00047	0.00042	0.999999	0.000952	0.000949	-0.00036
6343	127.55	1	3	0.000205	-0.01778	-17.9906	0.016889	0.010425	-0.02188	0.001849	0.001934	-0.0007	-0.00419	0.004038	0.000644	0.999999	0.000925	0.000967	-0.00035
6344	127.565	1	3	0.000456	-0.01762	-17.9909	0.0166	0.01069	-0.0214	0.00177	0.002021	-0.00069	-0.00629	0.007375	0.000836	0.999999	0.000885	0.00101	-0.00035
6345	127.585	1	3	0.000784	-0.01741	-17.9913	0.016189	0.011022	-0.02071	0.001617	0.002188	-0.00067	-0.00882	0.008627	0.000938	0.999999	0.000809	0.001094	-0.00034
6346	127.605	1	3	0.001103	-0.01718	-17.9917	0.015746	0.01132	-0.02	0.001422	0.002345	-0.00065	-0.01097	0.006592	0.001026	0.999999	0.000712	0.001172	-0.00033
6347	127.63	1	3	0.00149	-0.0169	-17.9922	0.015161	0.011631	-0.01911	0.001124	0.002415	-0.00063	-0.01233	-0.00161	0.001081	0.999999	0.000562	0.001208	-0.00031
6348	127.65	1	3	0.001788	-0.01666	-17.9926	0.014696	0.011826	-0.01844	0.000862	0.002316	-0.00061	-0.01431	-0.00794	0.001008	0.999999	0.000432	0.001158	-0.0003
6349	127.67	1	3	0.002078	-0.01642	-17.9929	0.014261	0.011964	-0.01781	0.000541	0.002131	-0.00059	-0.01765	-0.00998	0.000755	0.999999	0.000271	0.001066	-0.00029
6350	127.69	1	3	0.002359	-0.01618	-17.9933	0.013864	0.012034	-0.01723	0.000169	0.001926	-0.00058	-0.01897	-0.01044	0.000539	0.999999	8.46E-05	0.000963	-0.00029
6351	127.71	1	3	0.002633	-0.01594	-17.9936	0.013507	0.01203	-0.01671	-0.0002	0.001728	-0.00057	-0.01822	-0.00882	0.000496	1	-0.0001	0.000864	-0.00028
6352	127.73	1	3	0.002899	-0.0157	-17.994	0.013186	0.011955	-0.01621	-0.00056	0.001567	-0.00056	-0.0172	-0.00754	0.00039	1	-0.00028	0.000784	-0.00028
6353	127.745	1	3	0.003096	-0.01553	-17.9942	0.012964	0.011855	-0.01585	-0.00081	0.001456	-0.00055	-0.01603	-0.00719	0.000269	1	-0.0004	0.000728	-0.00028
6354	127.765	1	3	0.003352	-0.01529	-17.9945	0.012691	0.011666	-0.01542	-0.00111	0.001337	-0.00055	-0.01458	-0.00401	0.000113	1	-0.00056	0.000669	-0.00027
6355	127.785	1	3	0.003603	-0.01506	-17.9948	0.012435	0.011421	-0.01504	-0.00139	0.001293	-0.00055	-0.01342	-0.00106	-1.24E-05	1	-0.0007	0.000647	-0.00027

	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	19:AngQua	20:AngQua	21:AngQua	22:MotorR	23:MotorR	24:MotorR	25:MotorR	26:MotorR	27:MotorR	28:MotorR	29:MotorR	30:PosGPS	31:PosGPS	32:PosGPS[3]-alt(m)
6313	-0.00225	0.018197	0.014013	5232.76	5230.93	5232.54	5236.24	0	0	0	0	-0.01409	-0.02045	-17.9733
6314	-0.00366	0.016724	0.015233	5232.45	5227.9	5234.57	5236.25	0	0	0	0	-0.01365	-0.02046	-17.9738
6315	-0.00618	0.013837	0.015473	5227.91	5228.46	5239.45	5235.15	0	0	0	0	-0.01291	-0.02047	-17.9746
6316	-0.00852	0.0117	0.014401	5226.55	5231.23	5240.88	5233.5	0	0	0	0	-0.01233	-0.02047	-17.9753
6317	-0.01043	0.01048	0.012677	5226.3	5234.42	5239.85	5233.43	0	0	0	0	-0.01189	-0.02047	-17.9757
6318	-0.01361	0.009708	0.009361	5228.3	5235.41	5241.86	5232	0	0	0	0	-0.01117	-0.02046	-17.9765
6319	-0.01638	0.010443	0.004202	5228.35	5240.01	5239.32	5235.38	0	0	0	0	-0.0106	-0.02045	-17.9771
6320	-0.01827	0.011708	0.002386	5232.24	5239.17	5239.9	5233.64	0	0	0	0	-0.01018	-0.02043	-17.9776
6321	-0.02125	0.014892	9.32E-05	5232.62	5237.87	5237.87	5239	0	0	0	0	-0.00948	-0.02041	-17.9784
6322	-0.02287	0.017115	-0.00291	5237.13	5238.95	5234.17	5240.25	0	0	0	0	-0.00907	-0.02039	-17.9789
6323	-0.02488	0.020504	-0.00348	5238.38	5237.2	5232.36	5243.05	0	0	0	0	-0.0084	-0.02034	-17.9796
6324	-0.02565	0.022008	-0.00225	5237.61	5237.55	5233.08	5241.36	0	0	0	0	-0.008	-0.02031	-17.9801
6325	-0.02634	0.023691	0.001856	5239.79	5235.09	5231.06	5239.22	0	0	0	0	-0.00735	-0.02025	-17.9809
6326	-0.02662	0.024097	0.004643	5238.9	5235.33	5231.29	5236.65	0	0	0	0	-0.00697	-0.0202	-17.9813
6327	-0.02693	0.023995	0.01244	5237.59	5234.93	5228.61	5232.71	0	0	0	0	-0.00635	-0.02011	-17.9821
6328	-0.02707	0.023399	0.019956	5231.96	5235.8	5226.74	5231.25	0	0	0	0	-0.00587	-0.02003	-17.9827
6329	-0.02669	0.022695	0.025224	5232.11	5233.86	5228.69	5225.41	0	0	0	0	-0.00539	-0.01994	-17.9833
6330	-0.02611	0.02223	0.030516	5230.18	5232.98	5226.6	5224.62	0	0	0	0	-0.00493	-0.01984	-17.9839
6331	-0.02544	0.022047	0.034785	5229.92	5230.13	5225.89	5223.9	0	0	0	0	-0.00447	-0.01973	-17.9845
6332	-0.02504	0.022021	0.036376	5229.6	5227.17	5226.08	5225.29	0	0	0	0	-0.00414	-0.01965	-17.985
6333	-0.02469	0.021918	0.036228	5230.65	5225.28	5227.05	5225.36	0	0	0	0	-0.00371	-0.01952	-17.9855
6334	-0.02487	0.021523	0.035363	5230.93	5226.75	5226.98	5224.7	0	0	0	0	-0.00317	-0.01935	-17.9862
6335	-0.02551	0.021049	0.033146	5228.48	5230.29	5224.87	5228.1	0	0	0	0	-0.00276	-0.01921	-17.9867
6336	-0.02588	0.020422	0.030249	5229.27	5231.71	5224.02	5229.78	0	0	0	0	-0.00236	-0.01906	-17.9872
6337	-0.02576	0.019785	0.027983	5224.82	5234.57	5224.6	5233.13	0	0	0	0	-0.00206	-0.01894	-17.9876
6338	-0.02466	0.019004	0.023592	5227.23	5234.86	5229.25	5230.38	0	0	0	0	-0.00168	-0.01878	-17.9881
6339	-0.02232	0.018566	0.021038	5231.21	5233.67	5231.36	5228.17	0	0	0	0	-0.00121	-0.01856	-17.9887
6340	-0.02045	0.018669	0.022784	5236.49	5229.64	5230.74	5225.72	0	0	0	0	-0.00084	-0.01838	-17.9892
6341	-0.0192	0.018782	0.025139	5234.54	5228.4	5230.43	5226.78	0	0	0	0	-0.00049	-0.01819	-17.9897
6342	-0.01862	0.018677	0.028019	5236.5	5227.1	5228.47	5225.07	0	0	0	0	-0.00014	-0.01799	-17.9901
6343	-0.01887	0.018196	0.031185	5237.3	5225.97	5226.46	5224.14	0	0	0	0	0.000205	-0.01778	-17.9906
6344	-0.01965	0.017458	0.0334	5234.47	5225.66	5226.57	5224.88	0	0	0	0	0.000456	-0.01762	-17.9909
6345	-0.02127	0.016004	0.035284	5229.04	5227.97	5224.57	5228.04	0	0	0	0	0.000784	-0.01741	-17.9913
6346	-0.02285	0.014136	0.035751	5226.85	5228.37	5221.96	5231.92	0	0	0	0	0.001103	-0.01718	-17.9917
6347	-0.0237	0.011227	0.035023	5223.2	5232.22	5221.53	5232.81	0	0	0	0	0.00149	-0.0169	-17.9922
6348	-0.02284	0.008693	0.032112	5225.56	5226.39	5224.93	5235.94	0	0	0	0	0.001788	-0.01666	-17.9926
6349	-0.02107	0.0056	0.030087	5227.04	5224.13	5229.45	5234.38	0	0	0	0	0.002078	-0.01642	-17.9929
6350	-0.01906	0.001964	0.027831	5227.6	5228.13	5231.53	5230.19	0	0	0	0	0.002359	-0.01618	-17.9933
6351	-0.01709	-0.00172	0.025245	5230.2	5228.85	5233.31	5227.87	0	0	0	0	0.002633	-0.01594	-17.9936
6352	-0.01549	-0.00521	0.024578	5227.94	5229.25	5233.25	5230.52	0	0	0	0	0.002899	-0.0157	-17.994
6353	-0.01439	-0.00768	0.022731	5228.16	5228.92	5234.78	5231.06	0	0	0	0	0.003096	-0.01552	-17.9942
6354	-0.01317	-0.01071	0.020063	5232.54	5227.3	5237.47	5228.48	0	0	0	0	0.003352	-0.01529	-17.9945
6355	-0.0127	-0.01347	0.018378	5230.17	5230.28	5235.36	5231.8	0	0	0	0	0.003603	-0.01506	-17.9948

CopterSim1

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3. Soft and hard basic use experiment

Scan the code or click the QR code to watch this experiment video tutorial

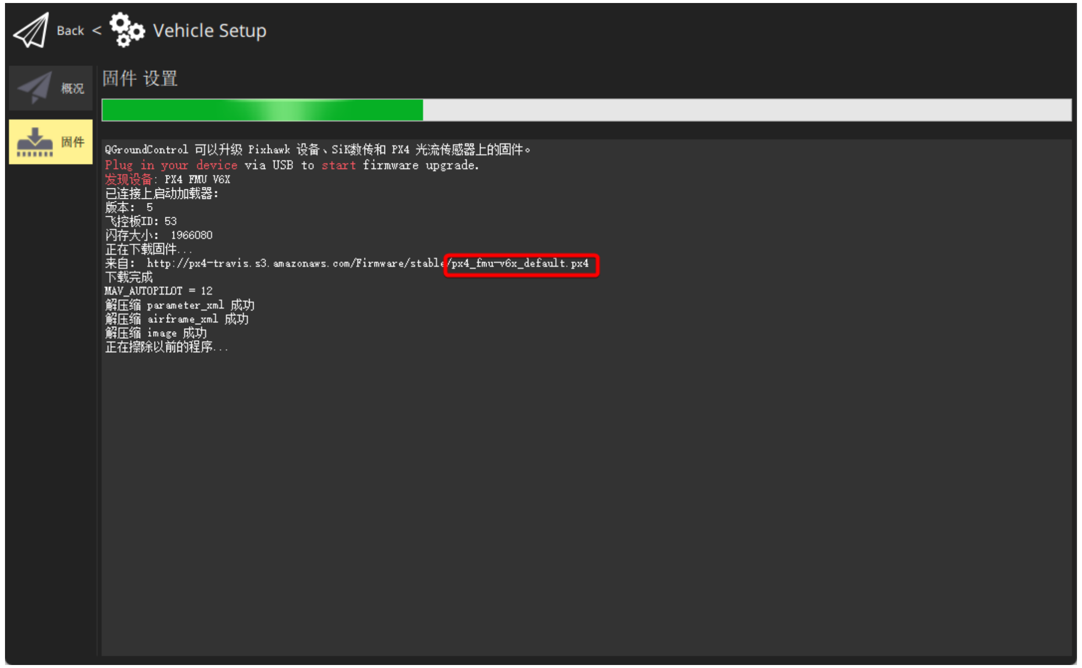
3.15 RflySim3D 3D scene loading experiment

This experiment mainly explains the loading process of RflySim3D 3D scene creation. Main folder see "*\PX4PSP\RflySimAPIs\2.RflySimUsage\1.BasicExps\e15_Scene-Load", the specific experimental operation see the file1.BasicExps\e15_Scene-Load\Readme.pdf,The experimental results are as follows (part) :

3. Soft and hard basic use experiment

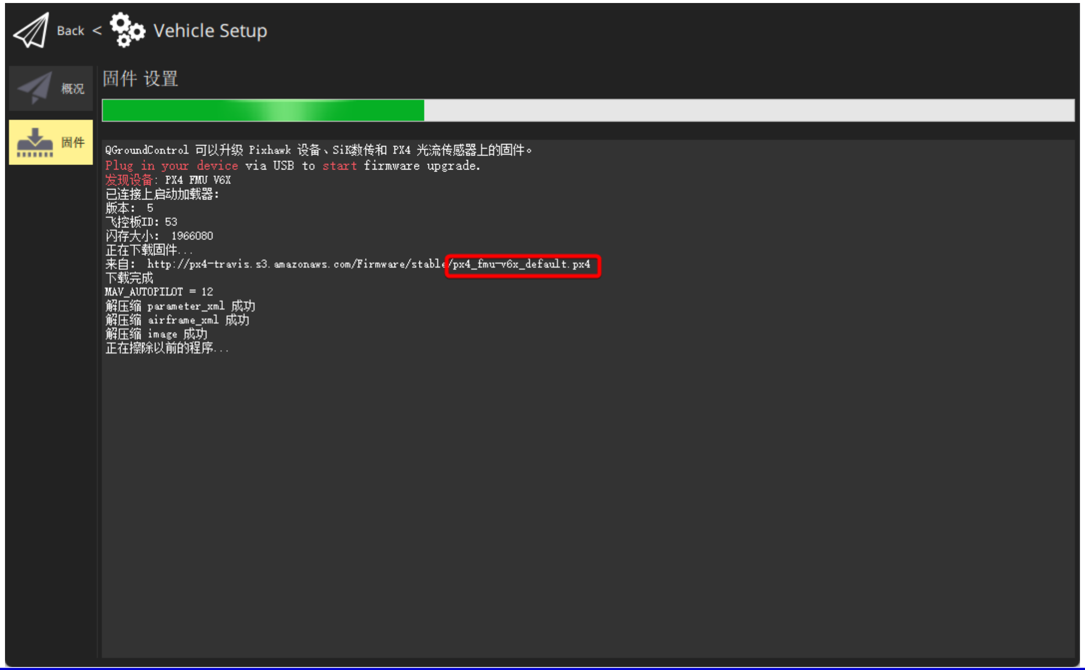
3.16 Pixhawk hardware compilation command recognition experiment

Aiming at different flight control hardware, this experiment introduces a compilation command to identify different flight control hardware by QGroundControl. See the document for detailed experimental operation1.BasicExps\e16_Identify-Hardware-Command\Readme.pdf,The experimental results are as follows (part) :



3.17 HIL route mapping experiment

This experiment introduces the method of using the route planning function in QGroundControl to draw the route and realize the flight under the specified route. See the document for detailed experimental operation1.BasicExps\e17_RoutePlanning\Readme.pdf,The experimental results are as follows (part) :



outline

1. Platform introduction and installation
2. Software and hardware introduction and usage
3. Soft and hard basic use experiment
4. Experimental preview in the following chapters
5. Future functions and prospects
6. Summarize

To purchase the teaching AIDS required for this course (already configured and ready to use, you can skip the hardware configuration part of this PPT), you can visit the following Taobao store link or scan the QR code on the right side of Taobao App https://shop212206553.taobao.com/

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RflySim tutorial

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4. Experimental preview in the following chapters

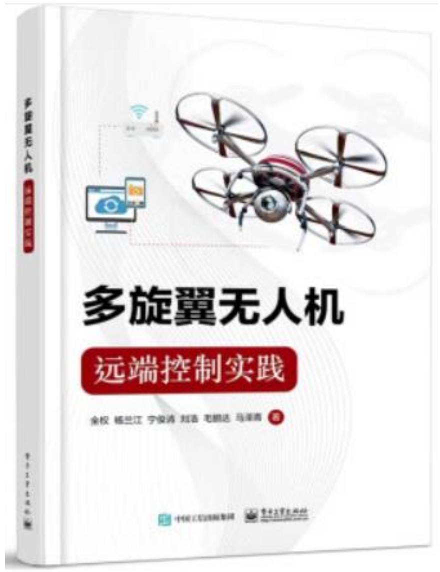
4.1 Companion Books

Design and Control of Multi-rotor Aircraft: This book teaches the basics of multi-rotor design, dynamic modeling, state estimation, control, and decision making. It involves the basic knowledge of air fluid mechanics, motor, circuit, material structure, theoretical mechanics, navigation, guidance and control, and has two basic and systematic characteristics. Therefore, it is helpful for readers to integrate the knowledge they have learned and focus on cultivating students' comprehensive ability to solve problems. This book covers most of the content of multi-rotor aircraft design, with fifteen chapters, including the fundamentals of multi-rotor aircraft, layout, power systems, modeling, perception, control, and decision-making. The purpose is to organize the design principles applied in the engineering practice of multi-rotor aircraft, and emphasize the importance of basic concepts, with basic, practical, comprehensive and systematic characteristics. This book can be used as a textbook for advanced undergraduate and graduate students, or as an introductory guide to research in the field, or as a self-study textbook for multi-rotor aircraft engineers.

Design and Control Practice of Multi-rotor Aircraft: This book is divided into two parts: experimental platform and experimental task, of which the experimental platform is based on the RflySim platform specially designed for this book. The RflySim platform uses the current advanced development concept of "Model-Based Design" process to tie together multi-rotor aircraft, Pixhawk autonomous vehicles, and MATLAB Simulink programming language. The experimental tasks include 8 progressive experiments: dynamic system design, dynamic modeling, sensor calibration, filter design, attitude controller design, fixed-point position controller design, semi-autonomous control mode design and fail-safe logic design, and complete the design and control practice of multi-rotor aircraft. This book is suitable for readers who are interested in the design and control of unmanned aerial vehicles, especially multi-rotor aircraft, and can also use some experiments in this book as practical links of professional courses.

4. Experimental preview in the following chapters

4.1 Companion Books



Multi-rotor Aircraft from Principle to Practice: This book is an introductory textbook on multi-rotor aircraft and a manual from principle to operational practice. It first introduces the basic concept, flight principle and development history of multi-rotor aircraft. Then, the system composition and important components such as frame, power system, communication system and flight control system are introduced in detail. Finally, the assembly and debugging, operation and maintenance, industry application and development are introduced. Generally speaking, this book has achieved the organic integration of theoretical explanation and practical operation, achieved the comprehensive and detailed content, and also explained the safety operation everywhere to cultivate the safety awareness of readers. We have also equipped the book with a large number of teaching and practical videos to help readers better learn and grasp the content of the book.

"Multi-rotor Vehicle Remote Control Practice" : This book aims at the application practice of multi-rotor UAV, aiming at lowering the entry threshold, providing a comprehensive reference textbook combining theory and practice for more higher vocational and lower grade undergraduates or related practitioners who do not have multi-rotor professional knowledge and development background, so that readers can apply the knowledge of basic professional and technical courses and professional courses after learning "automatic control principle" and other professional courses. The detailed design of the control system enables the reader to get practical training in the comprehensive application of professional theories to solve engineering problems.

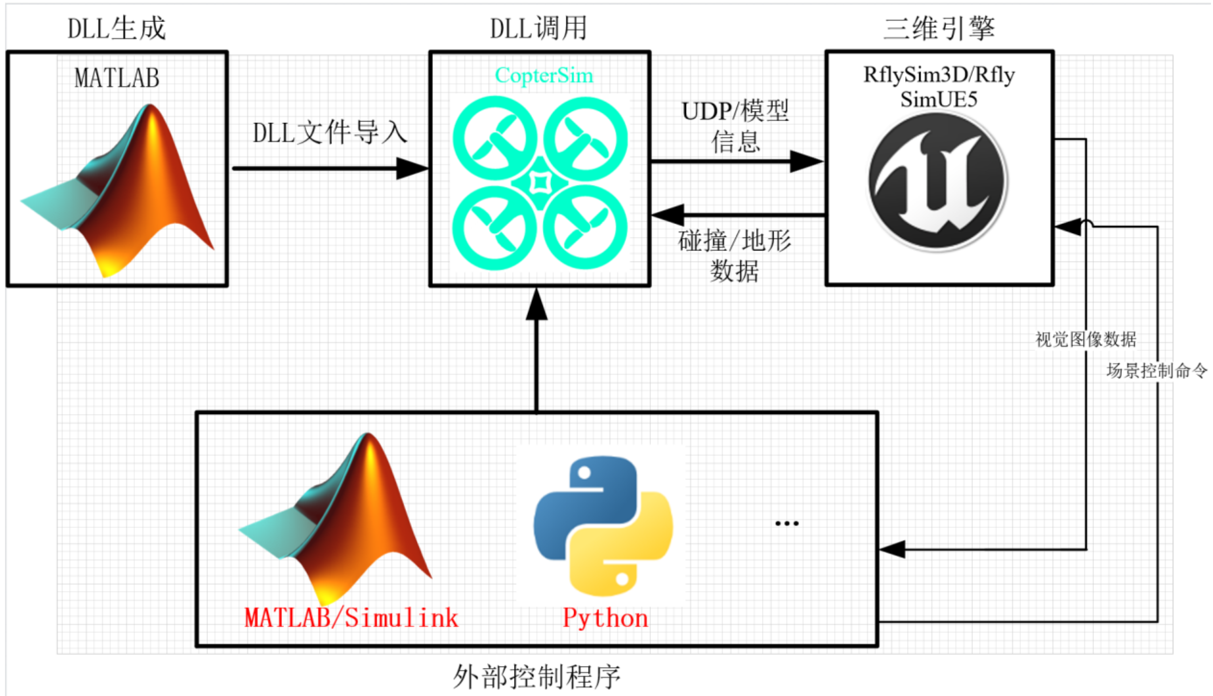
4. Experimental preview in the following chapters

4.2 Configuration and use of the experimental platform

The RflySim platform contains many software involved in the development process of unmanned system modeling, simulation, algorithm verification, etc., among which, Core components include CopterSim, QGroundControl, RflySim3D/RflySimUE5, Python38Env, Win10 WSL subsystem, SITL/HITLRun one-click script, MATLAB automatic code generation toolbox, Simulink cluster Control interface, PX4 Firmware source code, RflySim supporting documentation, and supporting hardware systems. By learning these core components, users can quickly start the development and testing of unmanned systems. The address of the API platform developed in this chapter is:API。The platform addresses of all the routines in this chapter are:Readme。

4.3 3D scene modeling and simulation

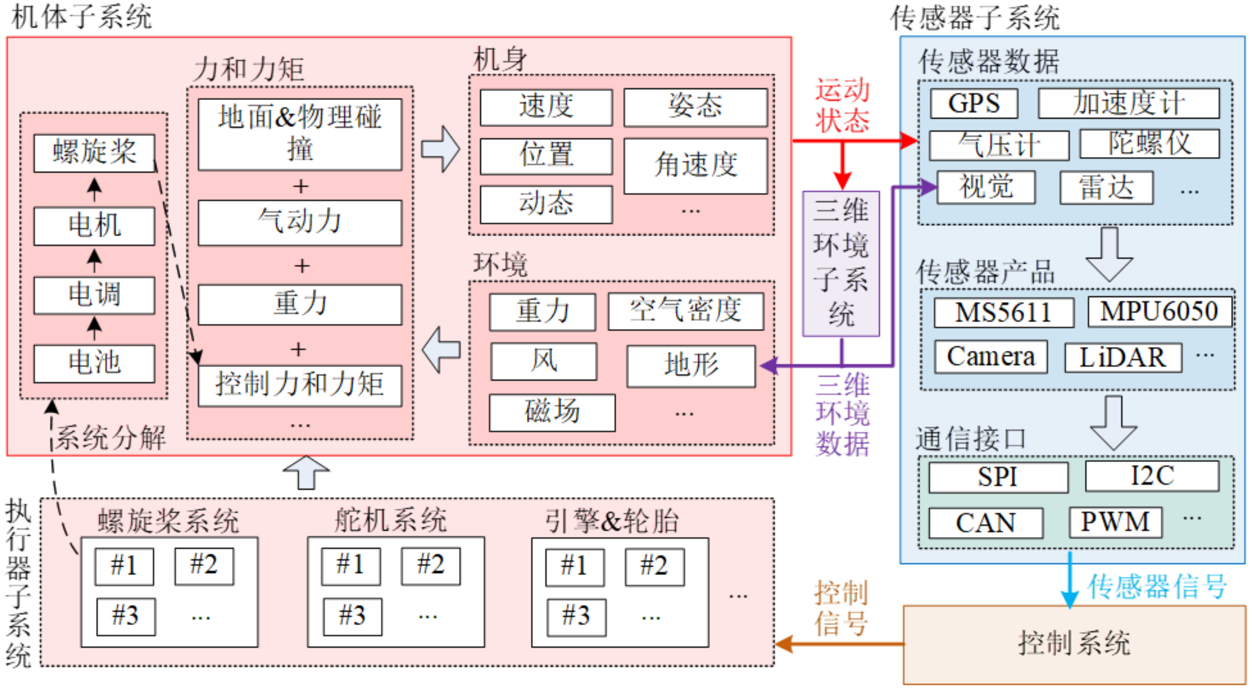
RflySim3D is a 3D simulation platform for RflySim. CopterSim will calculate the current state of the drone (mainly position and attitude dat a) according to the motor control data from Pixhawk (or PX4 SITL), an d then send these data to RflySim3D. RflySim3D will apply this data to t he corresponding drone in the scene, so that we can more intuitively see the status of the drone. RflySim3D also supports some configuration thr ough XML files, mainly using XML to configure the configuration of the UAV (four-rotor, six-rotor, fixed wing, etc.), the priority of the model in t he list, the name of the aircraft, the initial position and attitude of the ai rcraft, the initial position of each actuator (generally the rotor), the attit ude, the material, the rotation axis, and the motion mode. You can also d efine the position of the camera, you can also define some obstacle comp onents (such as posts, rings), and so on. The address of the API platform developed in this chapter is:API. The platform addresses of all the routi nes in this chapter are:Readme。



4. Experimental preview in the following chapters

4.4 Vehicle motion modeling and simulation

The unified modeling framework of unmanned vehicle system divides the whole unmanned vehicle system into two parts: fuselage system and control system. Sensor data and control signals are transmitted between the fuselage system and the control system. The fuselage system can be subdivided into four subsystems: the body subsystem, the actuator subsystem, the three-dimensional environment subsystem and the s ensor subsystem. In the whole modeling framework, the fuselage system needs to be modeled with high precision and implemented in real-ti me simulation: computer, and finally connected to the control system software or hardware, forming a software-in-the-loop simulation or har dware-in-the-loop simulation closed-loop. The address of the API platform developed in this chapter is:API. The platform addresses of all the routines in this chapter are:Readme。



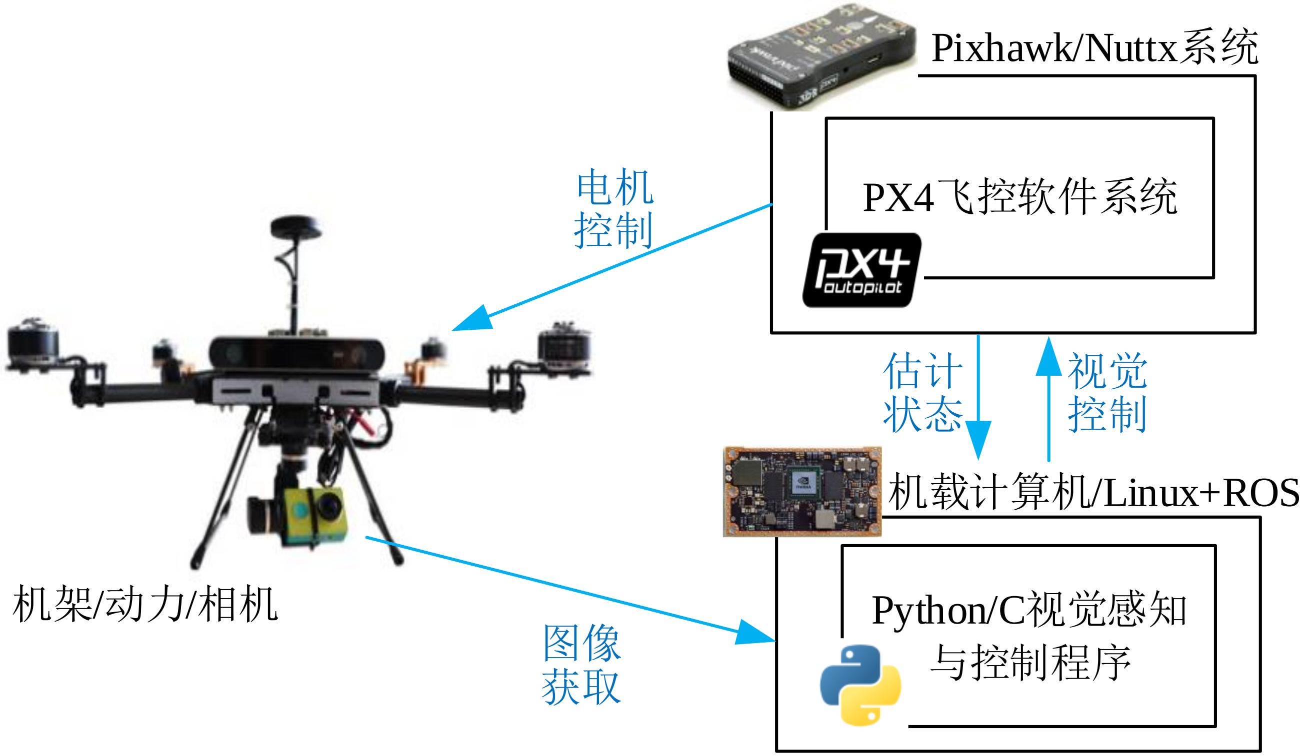
4. Experimental preview in the following chapters

4.5 Pose control and filter estimation

RflySim adopts the idea of Model-Based Design (MBD) and can be used for control and safety testing of unmanned systems. Through the following five stages: modeling stage, controller design stage, Software In the Loop simulation stage (SIL), Hardware In the Loop simulation stage (hardware-in-the-loop (HIL)) and real flight test stage. With MATLAB/Simulink's automatic code generation technology, the controller can be easily and automatically downloaded into the hardware for HIL simulation and real-world flight testing. The address of the API platform developed in this chapter is:API. The platform addresses of all the routines in this chapter are:Readme。

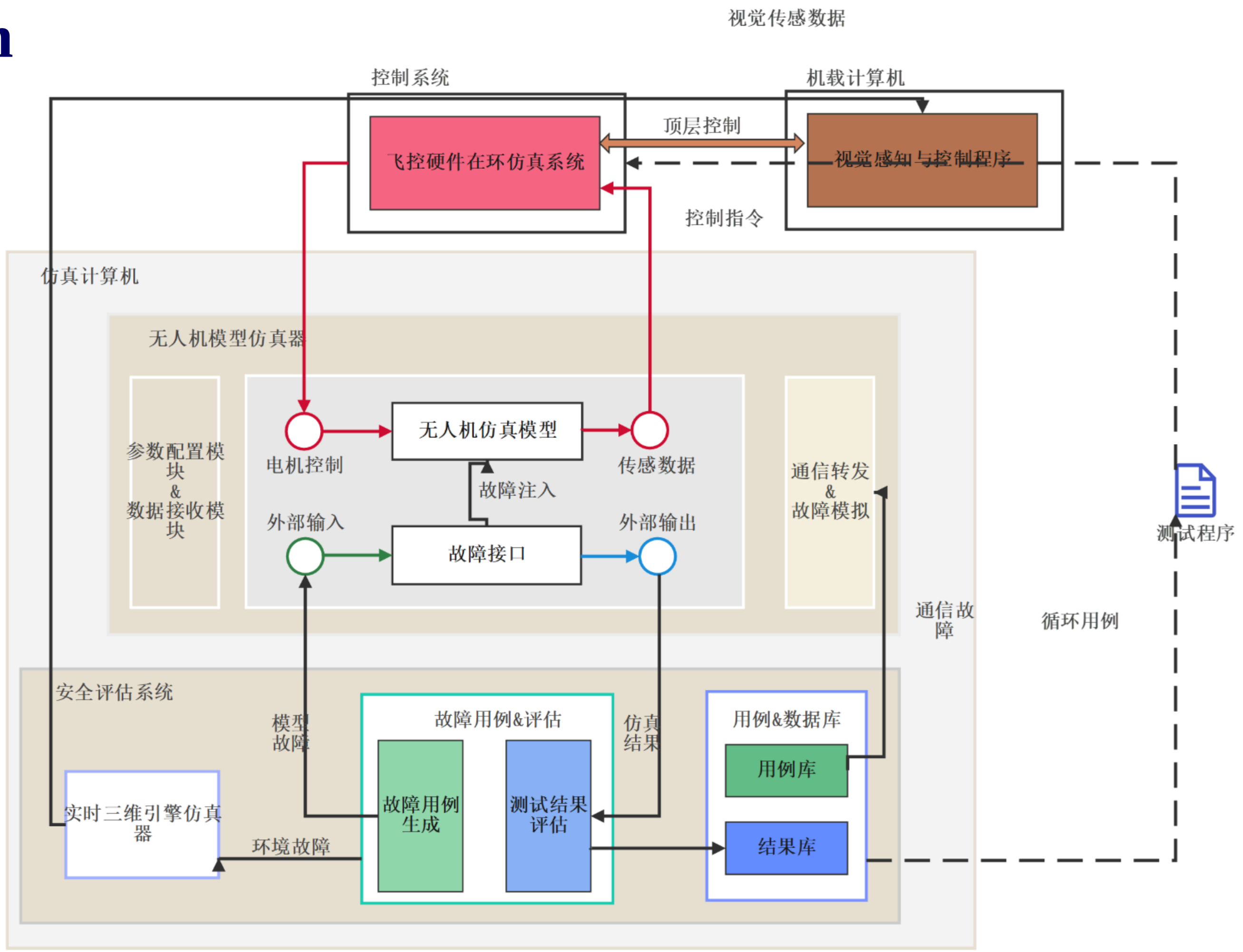
4.6 External control and trajectory planning

Uav is a kind of aircraft with autonomous flight ability, its external control ability is very important to achieve accurate flight tasks and safe flight operations. Common control methods are: remote control, ground station control, semi-autonomous control, and control through the corresponding interface of the computer. The external control theory mainly involves the stability of the aircraft in the air, which is generally understood as the position and attitude control of the UAV. In this regard, we will deeply discuss the rigid body model of the flight control of the UAV, that is, the guidance model. The address of the API platform developed in this chapter is:API. The platform addresses of all the routines in this chapter are:Readme。



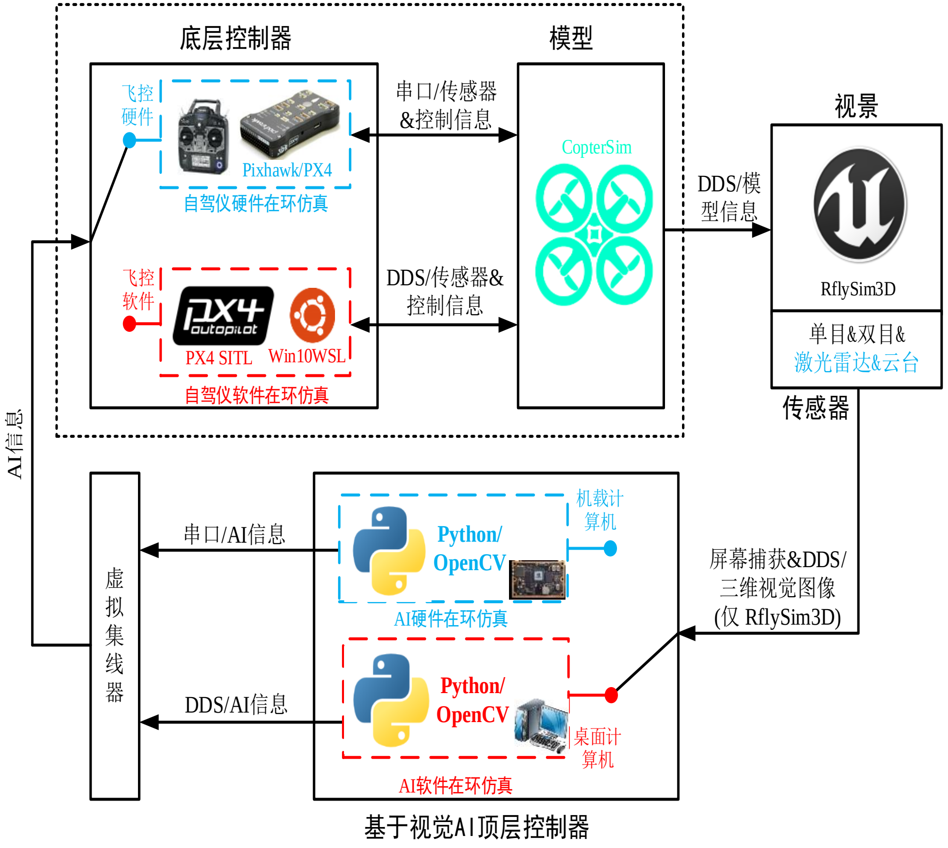
4.7 Safety Test and Health Platform

RflySim fault injection architecture is composed of physical module, simulation module and evaluation module. The physical module is composed of flight control hardware, which is responsible for connecting with the simulation computer, receiving control instructions from the outside and making attitude response, forming a semi-physical simulation closed loop, which can carry out real-time fault injection of hardware in the loop through flight control. The simulation module is composed of CopterSim, RFlySim3D and QGC, which is responsible for sending fault message and 3D fault injection of the whole machine, and carrying out real-time fault simulation. The evaluation module is responsible for the output of the safety condition after the fault injection. The address of the API platform developed in this chapter is:API. The platform addresses of all the routines in this chapter are:Readme。



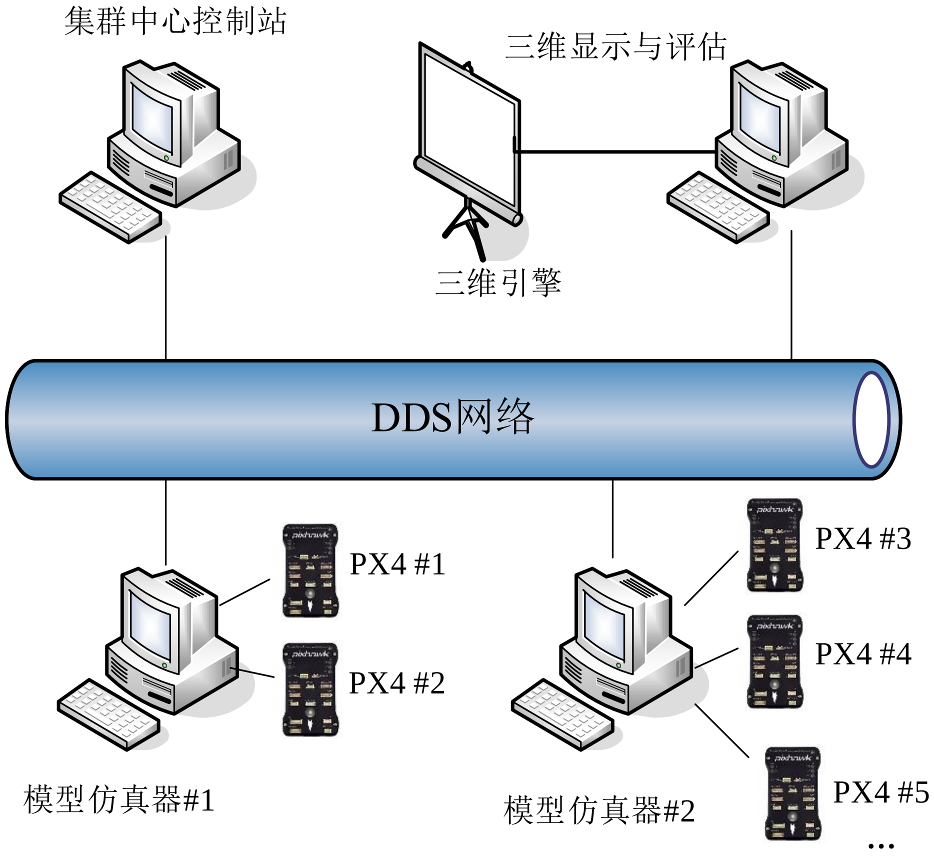
4.8 Visual perception and obstacle avoidance decision

The RflySim platform supports access to external sensors, and we divide these s ensor data into two categories: One kind of external sensors (magnetic compass , differential GPS, optical flow measurement, etc.) for direct flight control, the o ther kind of visual sensors (binocular, Lidar, depth camera, etc.) for direct fligh t control of airborne computers are directly generated and transmitted to Pixha wk flight control through Simulink and other programs, and the visual sensors are generated by three-dimensional environment engine. The images are trans mitted to the onboard computer. RflySim provides the depth camera sensor mo dule SDK for basic sensor parameters and installation position. Users can desig n orientation, focal length, field of view and other aspects of UAV-borne vision s ensors by setting relevant parameters, and customize the airborne vision modul e. The input/output interface of decision system is provided according to the inp ut/output interface protocol of decision making. The address of the API platfor m developed in this chapter is:API. The platform addresses of all the routines i n this chapter are:Readme。



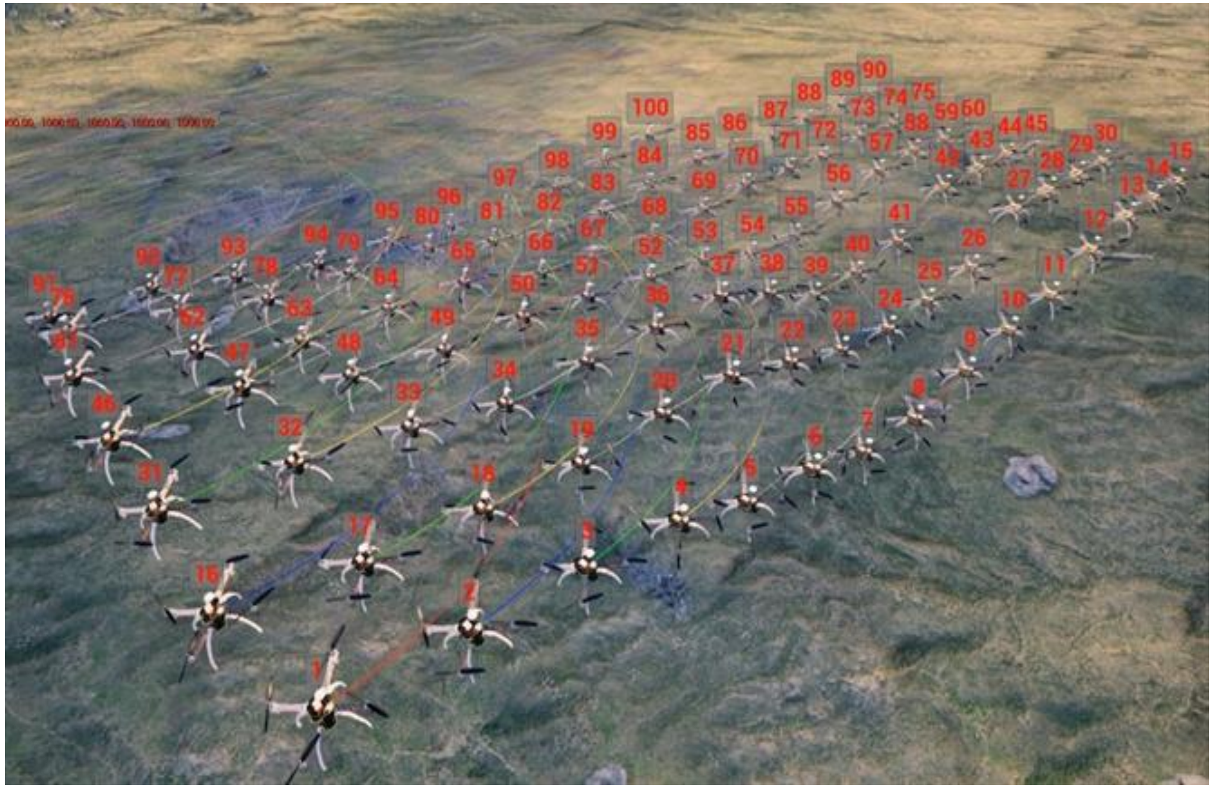
4.9 Communication Protocols and Cluster Networking

RflySim uses a distributed networking architecture so that different simulation models can run on the same computer or on different computers. Opening multiple model simulators and connecting multiple Pixhawk/PX4 autonomous vehicle hardware can form a multi-unmanned cluster simulation environment. Since the performance of a single computer is limited, the overall number of aircraft can be further expanded through the form of mutual communication between multiple computers in a LAN. The address of the API platform developed in this chapter is:API. The platform addresses of all the routines in this chapter are:Readme。



4.10 Cluster control and game confrontation

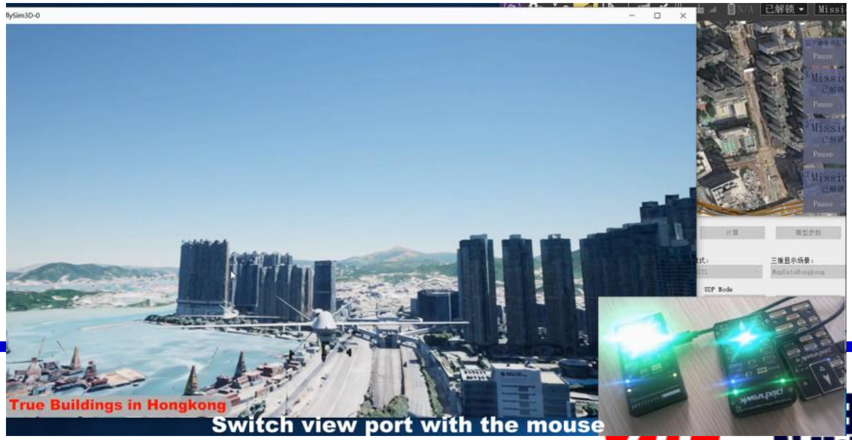
RflySim supports one-click start multi-machine cluster simulation function, supports MATLAB/Simulink, Python end cluster simulation development, supports multiple software in the ring, hardware in the ring and the combination of software and hardware virtual and real cluster simulation, supports the distributed cluster simulation of multiple computers in the LAN. At the same time, with the increase of the number of aircraft, the network communication load is getting larger and larger. In order to achieve more UAV cluster simulation with limited bandwidth, it is necessary to optimize the communication. At present, there are two main data protocols on the platform: Based on the MAVLink data and UDP compression architecture, RflySim proposes five compressed data protocols to realize the cluster simulation of hundreds of UAVs. The address of the API platform developed in this chapter is:API. The platform addresses of all the routines in this chapter are:Readme。

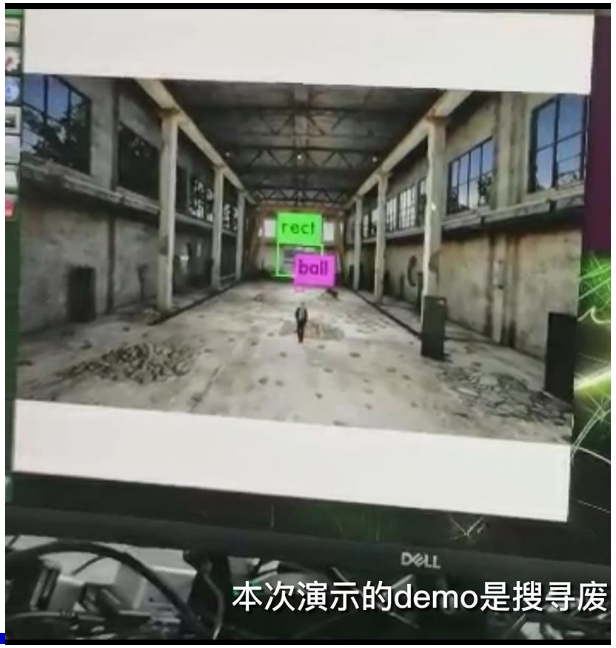


4. Experimental preview in the following chapters

4.11 Advanced video display

- Video 1: Multi-fixed-wing runway automatic takeoff and route hardware simulation test in the loop
- https://www.bilibili.com/video/BV13a411i7sH?p=16
- Video 2: Hardware-in-the-Loop simulation of Global Specified Scenarios (Changsha as an example)
- https://www.bilibili.com/video/BV13a411i7sH?p=17
- Video 3: Digital Twin & Virtual Reality, Hong Kong city map import with stand-alone hardware in the ring test
- https://www.bilibili.com/video/BV13a411i7sH?p=18
- Video 4: Hong Kong City map Tower Crossing cluster flight test
- https://www.bilibili.com/video/BV13a411i7sH?p=19
- Video 5: Multi-machine cluster hardware-in-the-loop simulation test system with vision
- https://www.bilibili.com/video/BV13a411i7sH?p=20





outline

1. Platform introduction and installation
2. Software and hardware introduction and usage
3. Soft and hard basic use experiment
4. Experimental preview in the following chapters
5. Future functions and prospects
6. Summarize

To purchase the teaching AIDS required for this course (already configured and ready to use, you can skip the hardware configuration part of this PPT), you can visit the following Taobao store link or scan the QR code on the right side of Taobao Apphttps://shop212206553.taobao.com/

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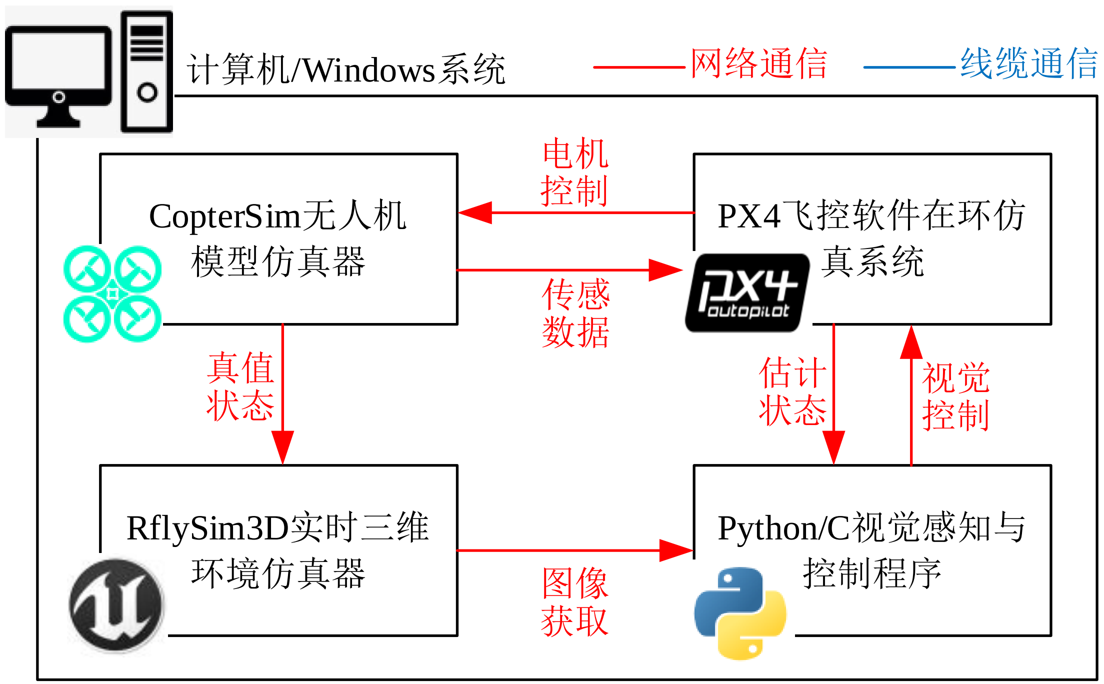
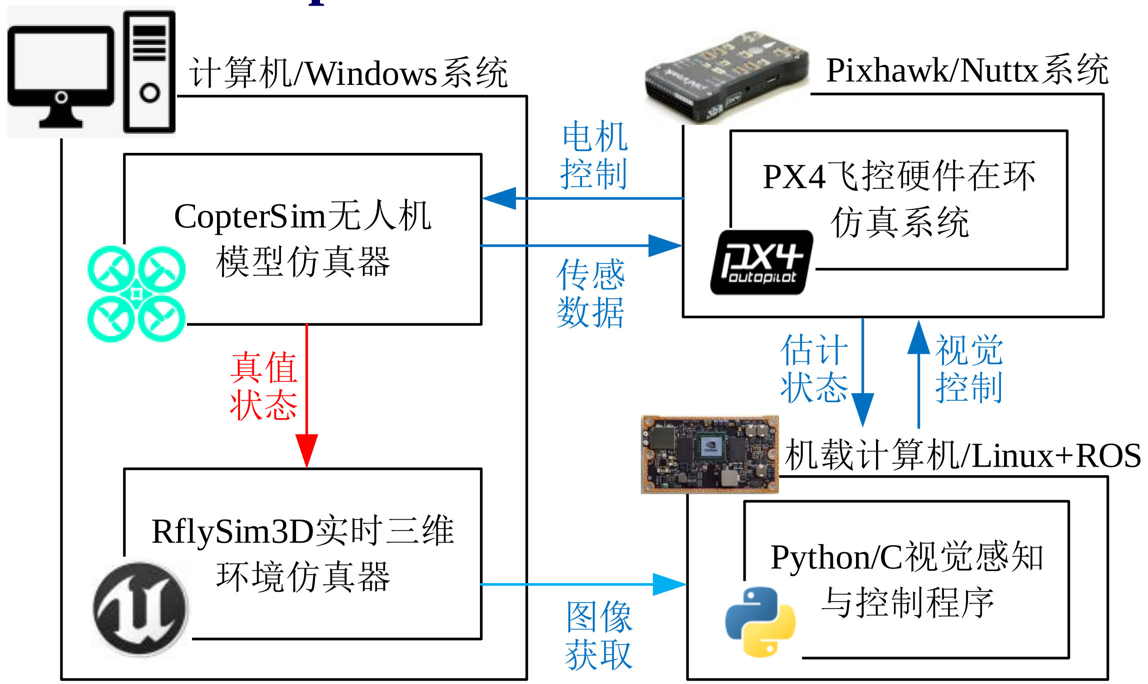
RflySim tutorial

5. Future functions and prospects

5.1 ROS-compatible top-level vision/decision algorithm development



(a) 单电脑Windows下纯软件在环开发模式

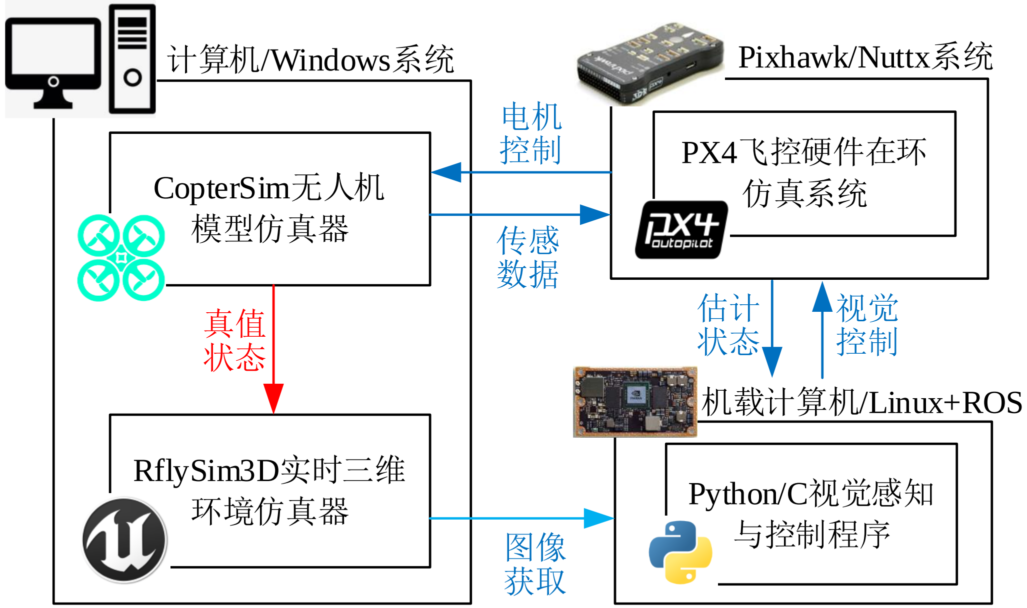


(b) “自驾仪+通信链路+机载计算机”硬件在环仿真

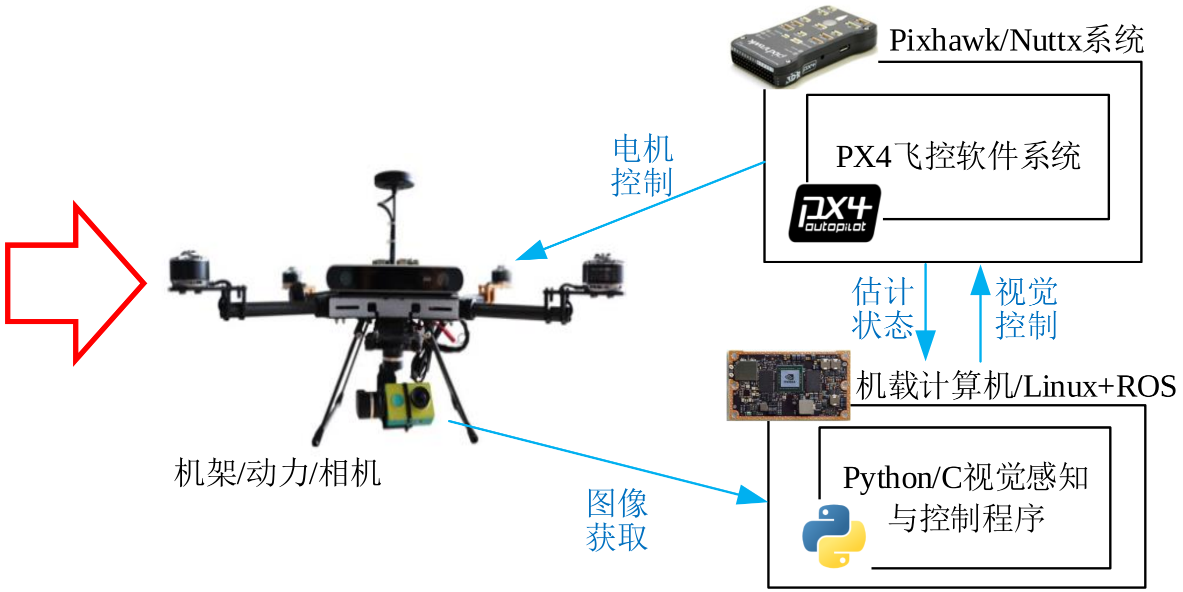
- **Develop and test a single visual function on a single computer, with low cost and high efficiency; Developed under Windows, easy to use, low threshold;**
- **Test the whole vision & decision under multi-hardware, more realistic and highly credible; Developed under Linux/ROS, this conforms to the actual development.**

5. Future functions and prospects

5.2 Migration process of reliable vision algorithm



(b) “自驾仪+通信链路+机载计算机”硬件在环仿真



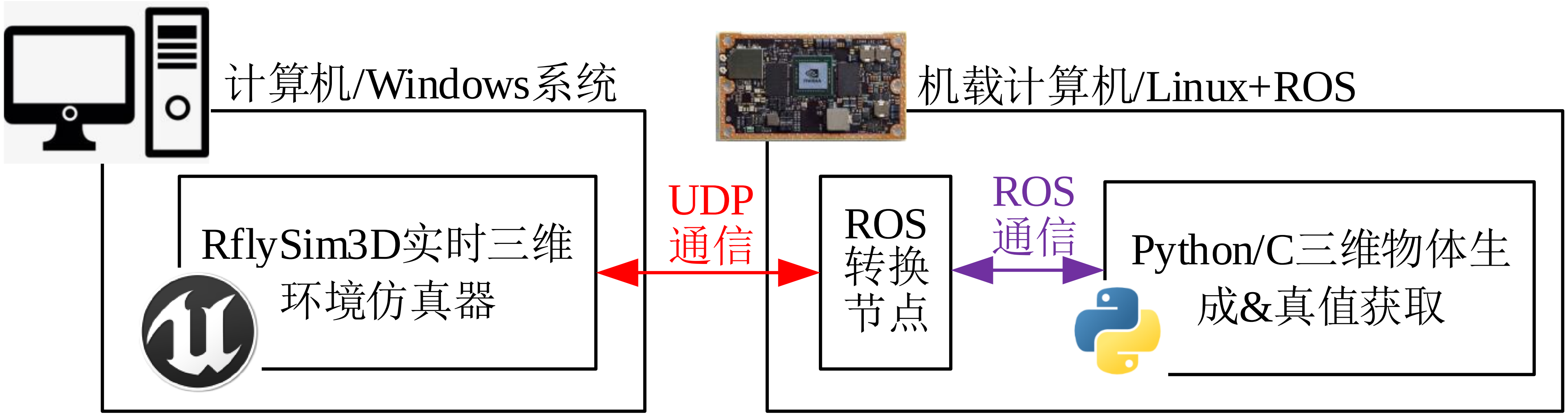
(c) “机架+自驾仪+通信链路+机载计算机”真机实验

- **The PWM output of Pixhawk/PX4 flight control is directly plugged into the rack power system, and the image acquisition interface is connected to the camera to complete the real machine migration. Pros: Seamless, does not require any additional modifications, highly realistic 3D scenes**

5. Future functions and prospects

5.3 Dynamic Generation and configuration of environment scenarios and Obstacles

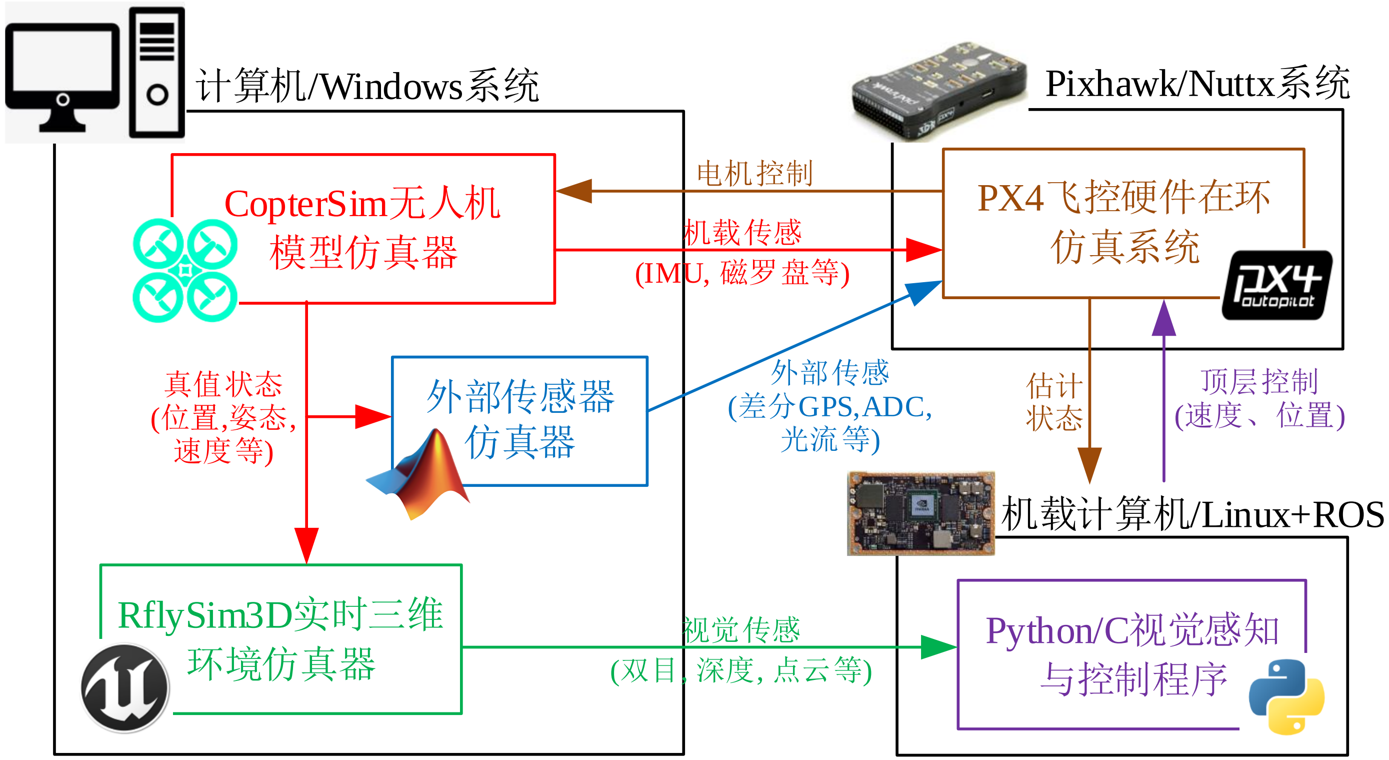
- **Support through UDP/ROS to dynamically change the scene map, change the 3D style of the aircraft, dynamically create obstacles (other aircraft, tracking targets, people, calibration board, tables and chairs, etc.), dynamically change the aircraft perspective (position, direction, focal length, etc.), change the 3D engine output image resolution, etc.**



5. Future functions and prospects

5.4 External Sensor Support

- Sensor data is divided into two categories: external sensors for direct flight control (magnetic compass, differential GPS, optical flow measurement, etc.), and vision sensors for direct on-board computers (binocular, Lidar, depth camera, etc.).
- The flight control sensor generates and feeds the Pixhawk flight control directly through Simulink and other programs
- The vision sensor is generated by the RflySim3D 3D environment engine and is transmitted to the onboard computer along with the image

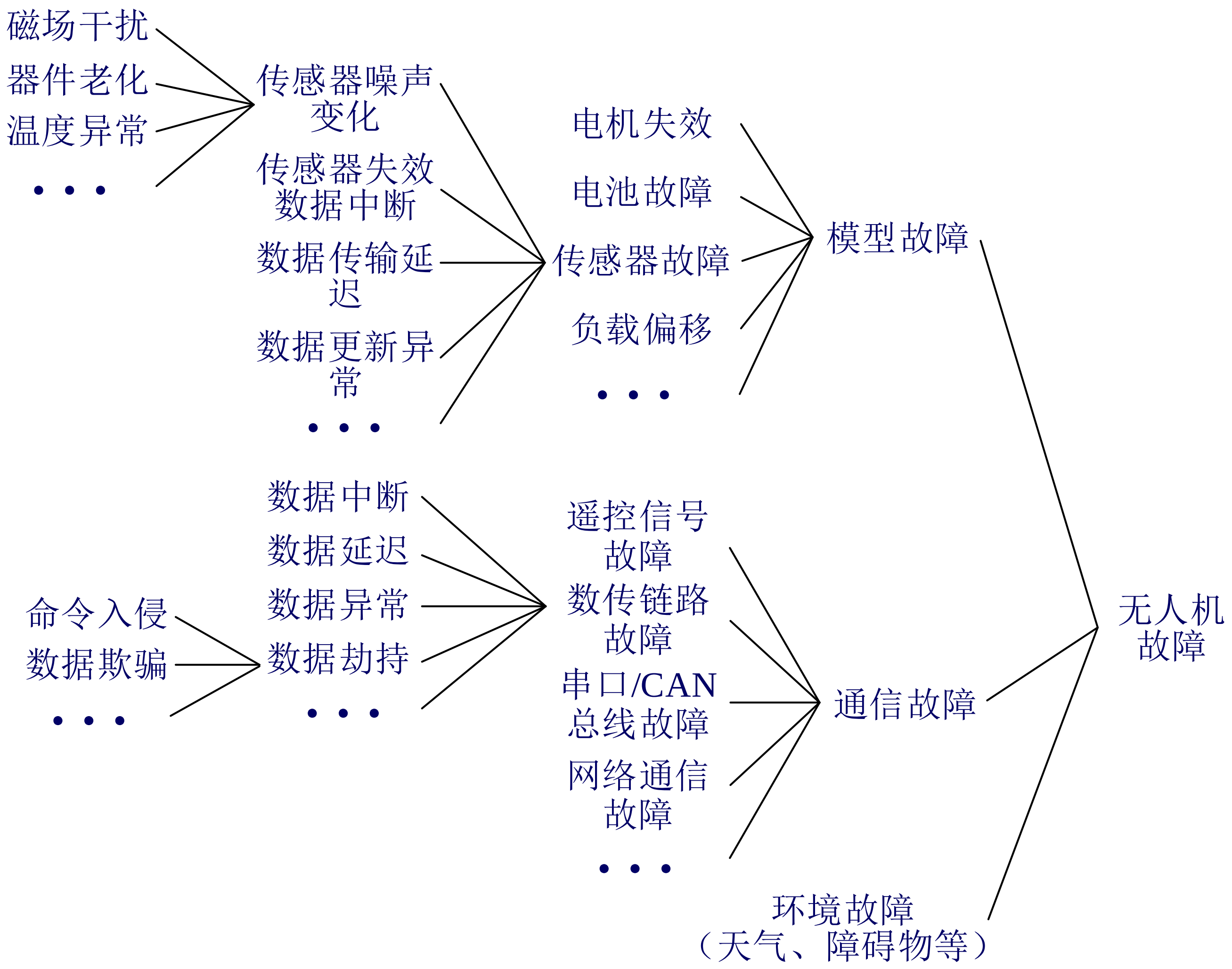


Note: Our RflySim3D environment Engine is based on Unreal Engine 4, just like Airsim, so it can support all of Airsim's existing sensors

5. Future functions and prospects

5.5 Fault Modeling and Injection

- **In addition to the testing of basic functions, the safety/reliability testing of the UAV in the event of failure is also critical.**
- **This system summarizes faults into three categories:**
- **Model failure**
- **Communication failure (related to interactive data transmission)**
- **Environmental failure (related to 3D scenes)**



5. Future functions and prospects

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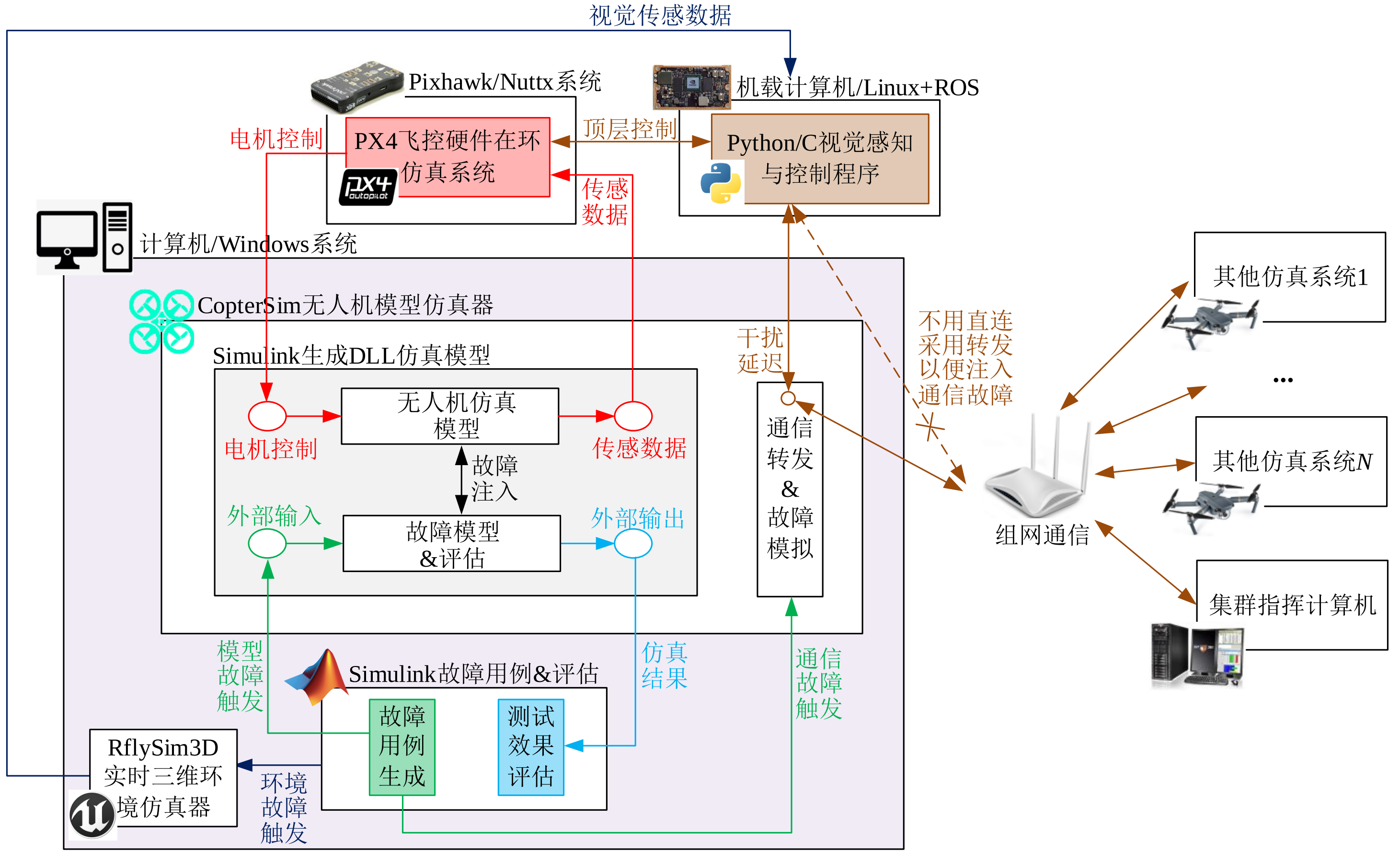

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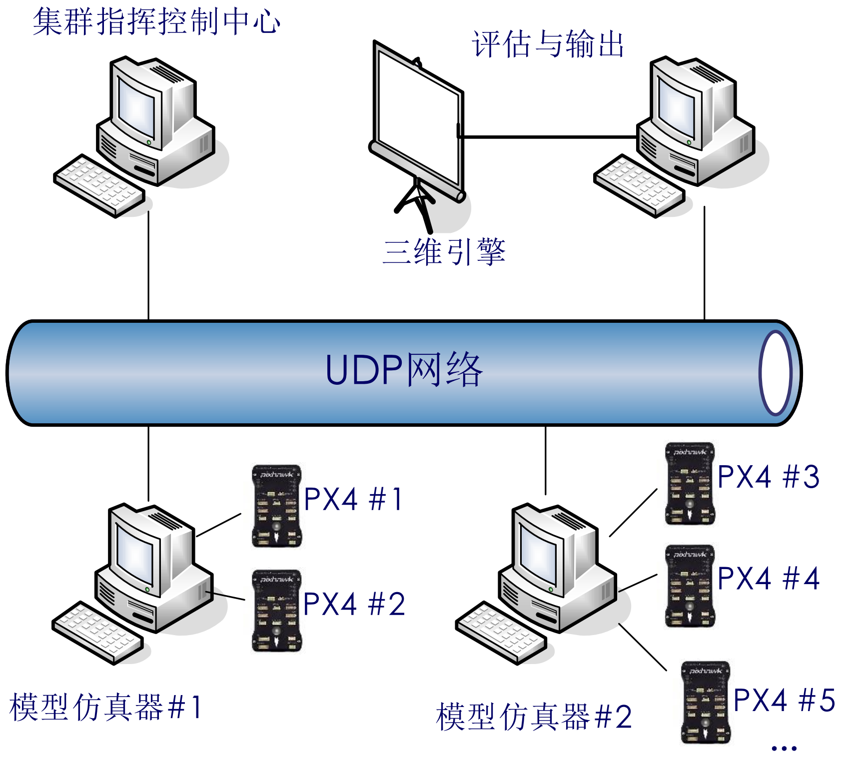
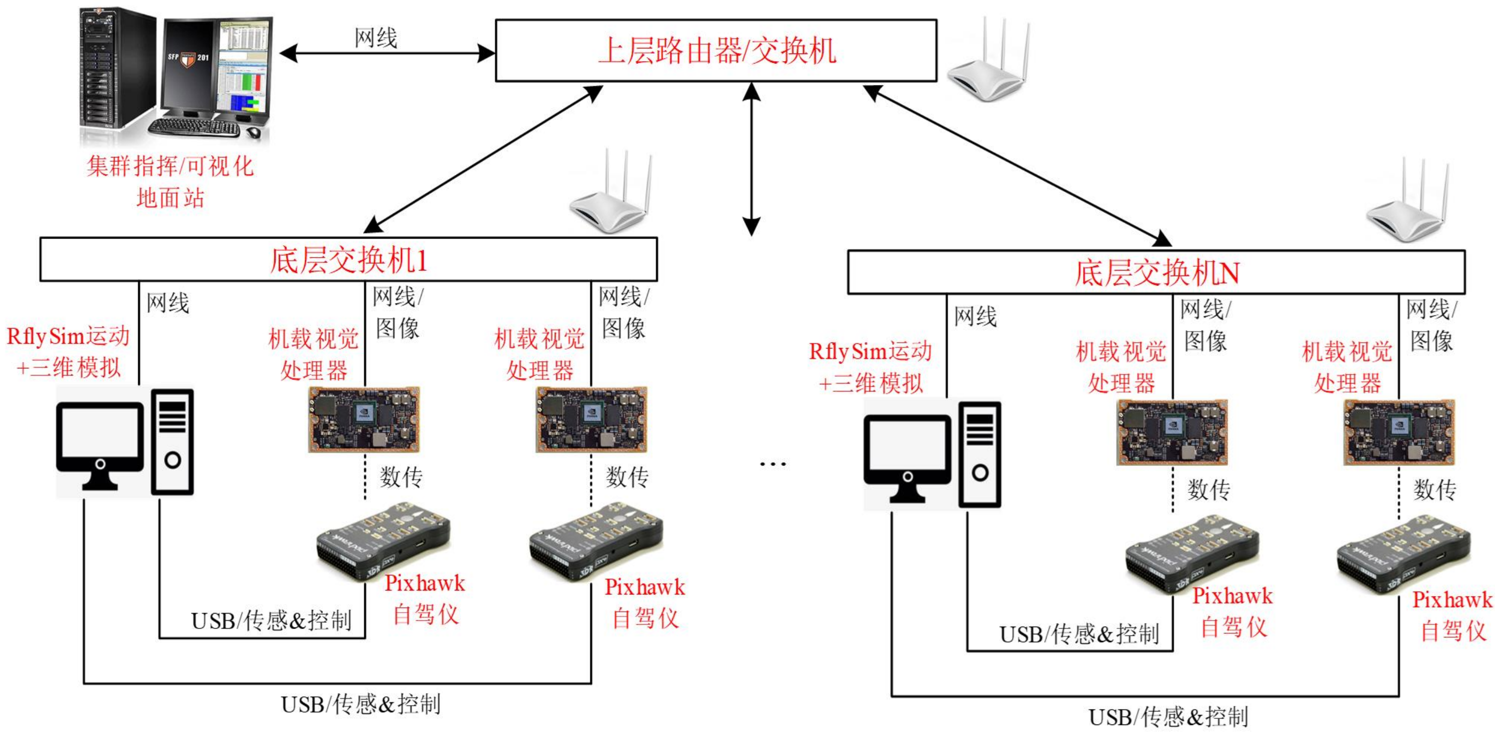
5. Future functions and prospects

5.6 Distributed simulation framework



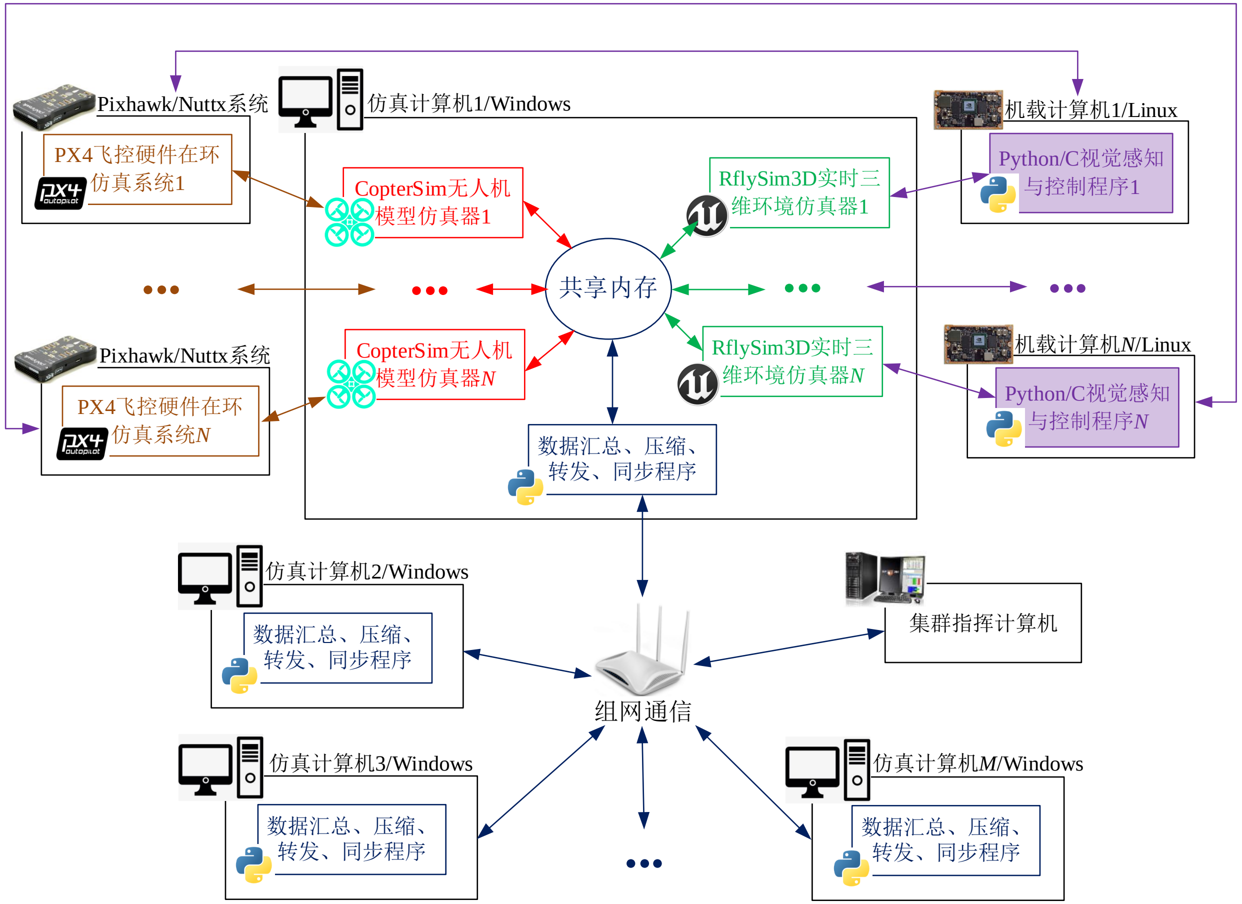
Invisible cluster formation



Swarm exploration with visual drones

5.7 Distributed communication optimization

- The communication between the various programs inside the computer adopts the shared memory mode, and the operation is directly on the memory, with the lowest delay and the fastest speed.
- Each computer can turn on multiple hardware/software in-loop simulation systems to simulate multiple UAVs.
- The data sent and received by each computer is summarized and compressed to ensure smooth communication within the network.
- Request communication (DDS) protocol is adopted to support thousand-frame simulation.

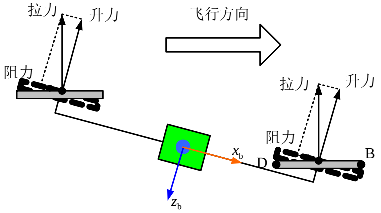


5. Future functions and prospects

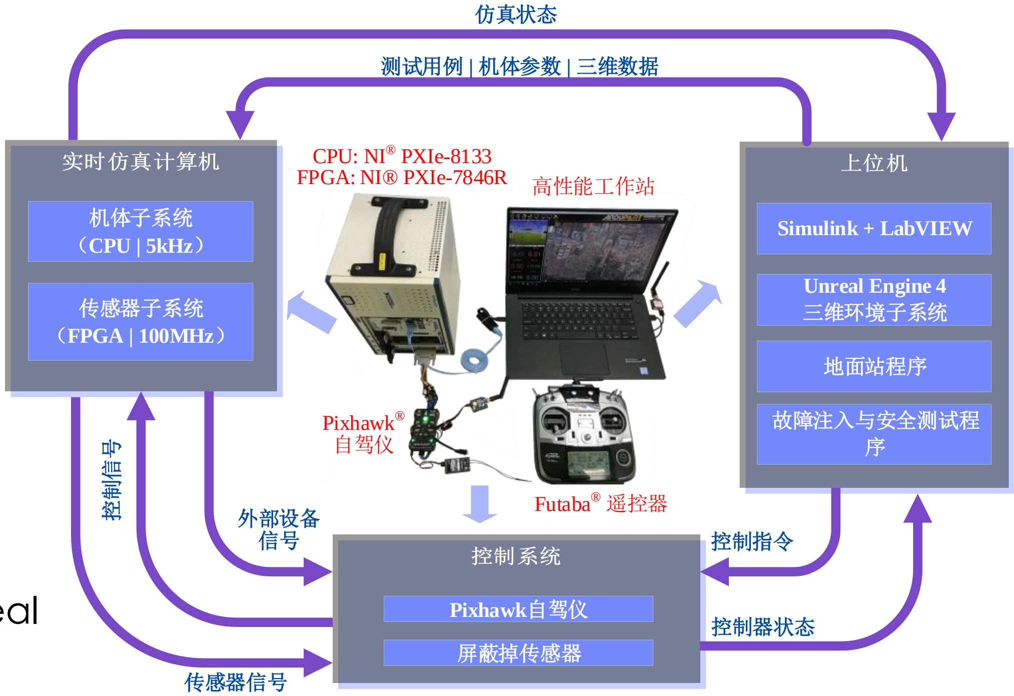
5.8 FPGA real-time simulation system, free from PX4 restrictions, supports other flight control hardware

Trusted hardware platform

Trusted software platform



Trusted simulation model



Simulation reliability assurance:

1. The simulation platform itself needs to have sufficient credibility.

➢ Hardware level: The hardware structure needs to be as close to the real system as possible.

➢ Software level: The simulation development process needs to be standard and reliable.

2. The mathematical simulation model should be accurate and reliable enough.

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RflySim tutorial

6. Summarize

- RflySim platform introduction and one-click installation, and the platform software and hardware configuration and use are introduced.
- The platform configuration experiment is designed to help students quickly get started with RflySim configuration and use by means of experiments.
- A general preview of the main content of the following chapters is provided to help students fully understand all the routines and teaching materials included in the platform.

If in doubt, scan the QR code below or https://doc.rflysim.com/ Find out more.

More tutorials for RflySim

Scan code consultation and exchange

RflySim technical exchange group

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Thank you!