

1. 实验名称及目的

1.1 实验名称

四旋翼分布式轨迹跟踪实验 (2Win or 4Win)

1.2 实验目的

本实验旨在通过RflySim仿真平台，实现四旋翼无人机集群的分布式控制与协同轨迹跟踪。通过配置分布式仿真环境，掌握多无人机系统的协调控制方法，理解领航-跟随编队控制策略的实现原理，并验证无人机集群在复杂轨迹跟踪任务中的协同能力。

1.3 关键知识点

关键知识点1：分布式仿真系统架构与配置方法

分布式仿真系统采用主节点控制、多节点分布部署的架构模式，通过Git实现自动化代码分发与部署。系统通过JSON配置文件管理各仿真节点，实现了主控节点集中开发调试、其他节点自动同步部署的高效协同仿真流程。

关键知识点2：多无人机领航-跟随编队控制算法实现

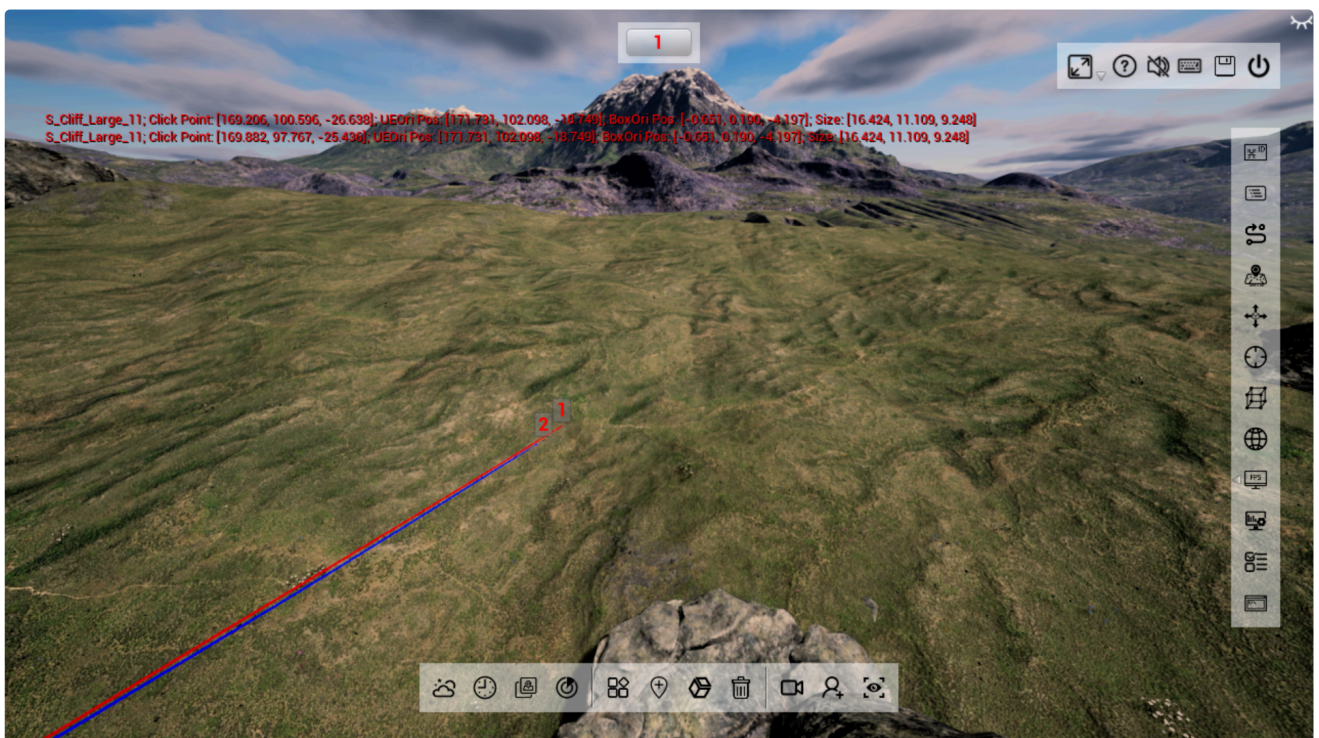
采用领航-跟随 (Leader-Follower) 编队控制模式，首架无人机作为领航者执行随机轨迹飞行，其余无人机作为跟随者基于领航者位置信息进行跟随飞行。通过状态信息共享和控制算法实现无人机集群的协调运动。

关键知识点3：基于UDP网络通信的无人机状态信息共享机制

系统通过UDP网络通信实现无人机间的状态信息共享，领航者将自身状态信息广播到指定网络端口，跟随者订阅这些信息并据此调整自己的飞行姿态，从而实现集群协同。

2. 实验效果

在RflySim 3D中看到实验效果，pc1的1号飞机随机飞行，pc2的2号飞机跟随1号飞机。



3. 文件目录

例程目录：[\[安装目录\]\RflySimAPIs\10.RflySimSwarm\3.CustExps\e0.CustApiExps\2.DistSimCommAPIExps\2.FourUAVSwarmDistSim](#)

序号	文件名	文件描述
1	[DistSimMasterFlowCtrl.py] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/DistSimMasterFlowCtrl.py)	分布式仿真用于解析器
2	[LaunchGitBareServer.bat] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/LaunchGitBareServer.bat)	启动Git裸用于代码分
3	[Python38Run.bat] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/Python38Run.bat)	设置Pythc
4	[simulation_config.json] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/simulation_config.json)	仿真配置文
5	[deploys\uavSwarm-win\CloseAll.bat] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/deploys/uavSwarm-win/CloseAll.bat)	关闭所有仿
6	[deploys\uavSwarm-win\SITLRun4MavlinkFull.bat] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/deploys/uavSwarm-win/SITLRun4MavlinkFull.bat)	启动SITL仿
7	[deploys\uavSwarm-win\UAVCtrl.py] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/deploys/uavSwarm-win/UAVCtrl.py)	无人机控制
8	[deploys\uavSwarm-win\UavPythonRunALL.bat] (file:///f:/git/10.RflySimSwarm/SourceCode/DistSimExps/e4_FourUAVSwarmDistSim/deploys/uavSwarm-win/UavPythonRunALL.bat)	启动所有仿

4. 运行环境

4.1 软件要求

Windows 10及以上版本，RflySim工具链

4.2 硬件要求

笔记本/台式电脑2/4，交换机，网线2/4

①：安装方式请见：<https://rflysim.com/doc/zh/HowToInstall.pdf>

5. 实验步骤

5.1 步骤1：实验前准备

1. 根据

[\[安装目录\]\PX4PSP\RflySimAPIs\10.RflySimSwarm\3.CustExps\e0.CustApiExps\2.DistSimCommAPIExps\1.HelloWorldTestExp\R](#)
[eadme.pdf](#)"

进行配置DistSim软件，保证局域网内电脑可以相互通信，在进行以下操作。


```
C:\WINDOWS\system32\cmd. x + v
Python3.8 environment has been set with openCV+pymavlink+numpy+pyulog etc.
You can use pip or pip3 command to install other libraries
Put Python38Run.bat into your code folder
Use the command: 'python XXX.py' to run the script with Python

C:\PX4PSP\RfLySimAPIS\10.RfLySimSwarm\CustomExps\4_FourUAVSwarmDistSim>python DistSimMasterFlowCtrl.py
HostIP is 192.168.31.75
2025-11-18 16:29:02.559: [PC1]执行指令: start /wait %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\UdpPortFree.bat 1
2025-11-18 16:29:05.085: [PC2]执行指令: start /wait %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\UdpPortFree.bat 2
2025-11-18 16:29:07.692: 预处理: 释放参与分布式仿真的节点已被占用的仿真资源 (软件、端口) ...
2025-11-18 16:29:07.692: 阶段1, 开始部署...
将重新部署各节点, 若有修改数据, 请先保存备份, 是否要继续? (Y/N): Y
```

5. 在pc1和pc2电脑会分别打开软件在环脚本, 等待2台电脑CopterSim初始化完成。

```
C:\WINDOWS\system32\cmd. x + v
Python3.8 environment has been set with openCV+pymavlink+numpy+pyulog etc.
You can use pip or pip3 command to install other libraries
Put Python38Run.bat into your code folder
Use the command: 'python XXX.py' to run the script with Python

C:\PX4PSP\RfLySimAPIS\10.RfLySimSwarm\CustomExps\4_FourUAVSwarmDistSim>python DistSimMasterFlowCtrl.py
HostIP is 192.168.31.75
2025-11-18 16:29:02.559: [PC1]执行指令: start /wait %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\UdpPortFree.bat 1
2025-11-18 16:29:05.085: [PC2]执行指令: start /wait %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\UdpPortFree.bat 2
2025-11-18 16:29:07.692: 预处理: 释放参与分布式仿真的节点已被占用的仿真资源 (软件、端口) ...
2025-11-18 16:29:07.692: 阶段1, 开始部署...
将重新部署各节点, 若有修改数据, 请先保存备份, 是否要继续? (Y/N): Y
2025-11-18 16:30:19.464: [PC1]执行指令: start LaunchGitBareServer.bat
2025-11-18 16:30:24.498: [PC1]执行指令: python %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\clone_git_last_version.py
git://192.168.151.2/uavSwarm-win PC1
2025-11-18 16:30:27.879: [PC2]执行指令: python %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\clone_git_last_version.py
git://192.168.151.2/uavSwarm-win PC2
2025-11-18 16:30:28.882: 阶段2, 启动仿真...
2025-11-18 16:30:28.886: [PC1]执行指令: start PC1\SITLRun4MavlinkFull.bat 1 1
2025-11-18 16:30:28.924: [PC2]执行指令: start PC2\SITLRun4MavlinkFull.bat 2 1
2025-11-18 16:30:30.951: 阶段3, 进行参与仿真的CopterSim状态检测...
2025-11-18 16:30:35.952: 正在检测局域网内的CopterID: [1, 2]
GetUe4EKFFinit listening on 224.0.0.10:20009, Start check the 3DFixed Status.
等待集群所有CopterSim完成初始化.CopterID 2 is GPS3DFixed.
等待集群所有CopterSim完成初始化...CopterID 1 is GPS3DFixed.
All CopterSim is GPS3DFixed. Now we can start the simulation.
2025-11-18 16:31:10.979: 阶段4, 启动仿真对象控制脚本...
2025-11-18 16:31:10.980: [PC1]执行指令: start PC1\UavPythonRunALL.bat 1 1
2025-11-18 16:31:11.019: [PC2]执行指令: start PC2\UavPythonRunALL.bat 2 1
2025-11-18 16:31:13.044: 阶段5, 进入用户操作...
```

6. 自动运行控制程序。

```
C:\WINDOWS\system32\cmd. x + v
Use the command: 'python XXX.py' to run the script with Python

C:\PX4PSP\RfLySimAPIS\10.RfLySimSwarm\CustomExps\4_FourUAVSwarmDistSim>python DistSimMasterFlowCtrl.py
HostIP is 192.168.31.75
2025-11-18 16:29:02.559: [PC1]执行指令: start /wait %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\UdpPortFree.bat 1
2025-11-18 16:29:05.085: [PC2]执行指令: start /wait %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\UdpPortFree.bat 2
2025-11-18 16:29:07.692: 预处理: 释放参与分布式仿真的节点已被占用的仿真资源 (软件、端口) ...
2025-11-18 16:29:07.692: 阶段1, 开始部署...
将重新部署各节点, 若有修改数据, 请先保存备份, 是否要继续? (Y/N): Y
2025-11-18 16:30:19.464: [PC1]执行指令: start LaunchGitBareServer.bat
2025-11-18 16:30:24.498: [PC1]执行指令: python %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\clone_git_last_version.py
git://192.168.151.2/uavSwarm-win PC1
2025-11-18 16:30:27.879: [PC2]执行指令: python %PSP_PATH%\RfLySimAPIS\RfLySimSDK\swarm\distsim\clone_git_last_version.py
git://192.168.151.2/uavSwarm-win PC2
2025-11-18 16:30:28.882: 阶段2, 启动仿真...
2025-11-18 16:30:28.886: [PC1]执行指令: start PC1\SITLRun4MavlinkFull.bat 1 1
2025-11-18 16:30:28.924: [PC2]执行指令: start PC2\SITLRun4MavlinkFull.bat 2 1
2025-11-18 16:30:30.951: 阶段3, 进行参与仿真的CopterSim状态检测...
2025-11-18 16:30:35.952: 正在检测局域网内的CopterID: [1, 2]
GetUe4EKFFinit listening on 224.0.0.10:20009, Start check the 3DFixed Status.
等待集群所有CopterSim完成初始化.CopterID 2 is GPS3DFixed.
等待集群所有CopterSim完成初始化...CopterID 1 is GPS3DFixed.
All CopterSim is GPS3DFixed. Now we can start the simulation.
2025-11-18 16:31:10.979: 阶段4, 启动仿真对象控制脚本...
2025-11-18 16:31:10.980: [PC1]执行指令: start PC1\UavPythonRunALL.bat 1 1
2025-11-18 16:31:11.019: [PC2]执行指令: start PC2\UavPythonRunALL.bat 2 1
2025-11-18 16:31:13.044: 阶段5, 进入用户操作...

输入任意指令, 结束分布式集群仿真, 关闭所有窗口
```

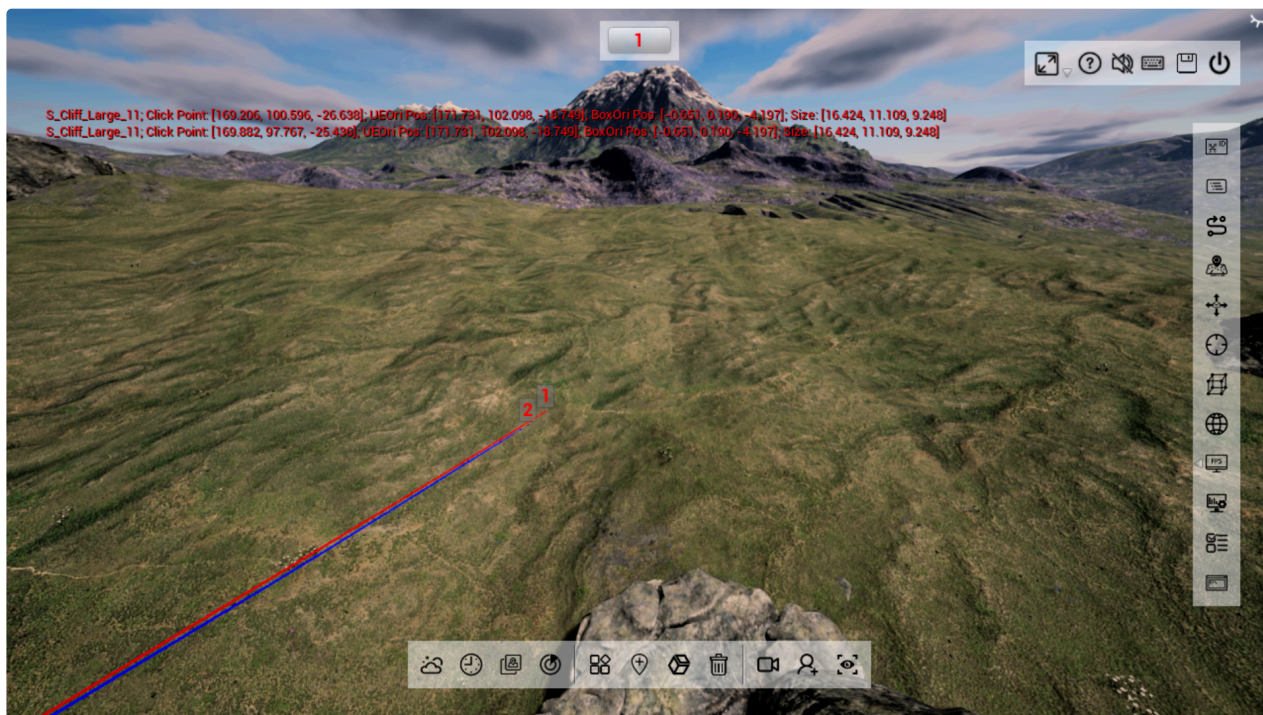
7. 在python终端可以看到无人机的实时状态。

```

C:\PX4PSP\Python38\python.exe
目标位置: X=65.99, Y=-0.62, Z=-23.68
目标位置: X=65.58, Y=1.36, Z=-23.65
目标位置: X=65.14, Y=3.35, Z=-23.63
目标位置: X=64.67, Y=5.34, Z=-23.61
目标位置: X=64.16, Y=7.32, Z=-23.59
目标位置: X=63.63, Y=9.30, Z=-23.57
领航者状态信息: 1 [-0.014875589869916439, 0.005005429964512587, -0.5869158506393433] [-0.018362725153565407, -0.005008898675441742, -0.028171323239803314] [-0.014875589869916439, 0.005005429964512587, -0.5869158506393433] [166.752685546875, 107.6338882446289, -22.20990562438965] [166.73047782467123, 107.62536799939124, -30.24390562397662]
目标位置: X=63.06, Y=11.27, Z=-23.54
目标位置: X=62.46, Y=13.24, Z=-23.52
目标位置: X=61.83, Y=15.21, Z=-23.50
目标位置: X=61.17, Y=17.19, Z=-23.47
目标位置: X=60.48, Y=19.15, Z=-23.45
目标位置: X=59.75, Y=21.11, Z=-23.42
目标位置: X=59.00, Y=23.06, Z=-23.40
目标位置: X=58.22, Y=25.00, Z=-23.38
目标位置: X=57.41, Y=26.94, Z=-23.35
目标位置: X=56.57, Y=28.87, Z=-23.33
领航者状态信息: 1 [-0.01358718890696764, 0.005058719776570797, -0.5849807858467102] [-0.01559560839086771, -0.013559820130467415, -0.030618172138929367] [-0.01358718890696764, 0.005058719776570797, -0.5849807858467102] [166.7454376220703, 107.63888549804688, -22.212491989135742] [166.72322989986654, 107.63036525280921, -30.246491988722713]
目标位置: X=55.71, Y=30.79, Z=-23.30
目标位置: X=54.82, Y=32.69, Z=-23.28
目标位置: X=53.90, Y=34.60, Z=-23.25
目标位置: X=52.95, Y=36.48, Z=-23.22
目标位置: X=51.98, Y=38.37, Z=-23.20
目标位置: X=50.98, Y=40.24, Z=-23.17
目标位置: X=49.95, Y=42.11, Z=-23.14

```

8. 可以在RflySim 3D中看到实验效果，pc1的1号飞机随机飞行，pc2的2号飞机跟随1号飞机。



9. 在运行python DistSimMasterFlowCtrl.py的命令行，按回车即可关闭所有仿真程序。

5.3步骤3: 4windows下运行分布式仿真系统 (选做)

1. 根据步骤1，进行4台windows电脑进行配置，并运行分布式仿真系统。
2. 进入到 e4_FourUAVSwarmDistSim4win 文件夹打开 e4_FourUAVSwarmDistSim4win\Python38Run.bat 输入python DistSimMasterFlowCtrl.py 并运行。

```

C:\WINDOWS\system32\cmd. x + v
Python3.8 environment has been set with openCV+pymavlink+numpy+pyulog etc.
You can use pip or pip3 command to install other libraries
Put Python38Run.bat into your code folder
Use the command: 'python XXX.py' to run the script with Python

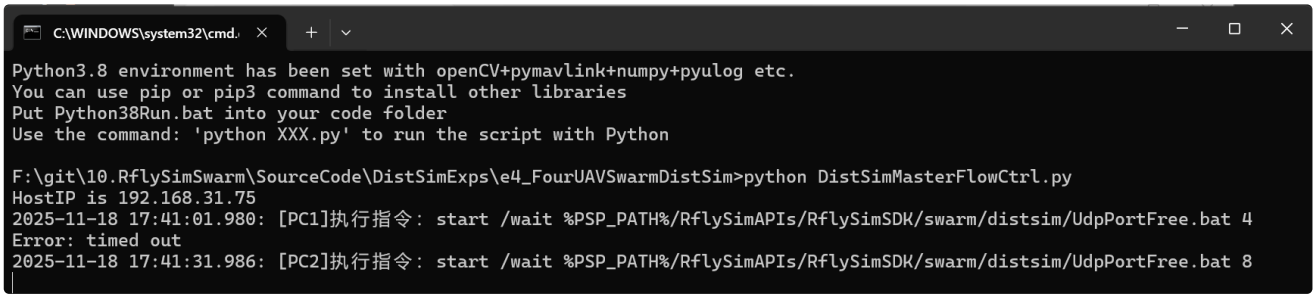
C:\PX4PSP\RflySimAPIs\10.RflySimSwarm\CustomExps\e4_FourUAVSwarmDistSim\4_FourUAVSwarmDistSim4win>python DistSimMasterFlowCtrl.py

```

3. 接下来会重复步骤5.2中4-9步骤，可以看到4台电脑8架无人机，跟随实验。

7.常见问题

**问题1: **运行DistSimMasterFlowCtrl.py脚本到LaunchGitBareServer.bat脚本时一直卡主死，如何处理？



```
C:\WINDOWS\system32\cmd. x + v
Python3.8 environment has been set with openCV+pymavlink+numpy+pyulog etc.
You can use pip or pip3 command to install other libraries
Put Python38Run.bat into your code folder
Use the command: 'python XXX.py' to run the script with Python

F:\git\10.RflySimSwarm\SourceCode\DistSimExps\e4_FourUAVSwarmDistSim>python DistSimMasterFlowCtrl.py
HostIP is 192.168.31.75
2025-11-18 17:41:01.980: [PC1]执行指令: start /wait %PSP_PATH%\RflySimAPIs\RflySimSDK\swarm\distsim/UdpPortFree.bat 4
Error: timed out
2025-11-18 17:41:31.986: [PC2]执行指令: start /wait %PSP_PATH%\RflySimAPIs\RflySimSDK\swarm\distsim/UdpPortFree.bat 8
```

答：需要确保2台电脑都有相同的磁盘，建议局域网内电脑RflySim工具链安装到同一磁盘下。

**问题2: 在进行4windows下运行分布式仿真系统时，准备步骤无法通信，如何处理？

答：请确保电脑A，电脑B，电脑C，电脑D的DistSim软件节点名称pc1 pc2 pc3 pc4分别对应。

6.参考资料

1.无