Contents

Vehicle motion modeling and simulation

In the early stage of the motion model design of unmanned system, it is necessary to est ablish accurate models of the controlled object and the environment according to the characte ristics of the whole system, and to model the controller according to the control requirements, so as to realize the system-level simulation as early as possible and grasp the dynamic beha vior of the system. In addition, the established object model and environment model can also be reused in other projects, which will also improve the progress of subsequent related projec t development.

In order to realize the idea of model-based development, a unified modeling framework based on modularization is proposed, which can be applied to various types of unmanned sys tems (unmanned aircraft, unmanned vehicles, unmanned ships, etc.) to ensure the reusability of the model framework, so that the comprehensive preliminary modeling can be quickly real ized in the early development stage of unmanned systems. On this basis, the subsequent auto matic development of the body system, control system and test system can be directly carried out. The modeling framework divides the vehicle motion model development of UAV syste m into six stages: modeling and identification, rapid control prototype, digital simulation verif ication, automatic code generation, hardware-in-the-loop simulation, and system integration an d test (as shown below).

FIG. 1 Model-based design block diagram of RFlySim platform1

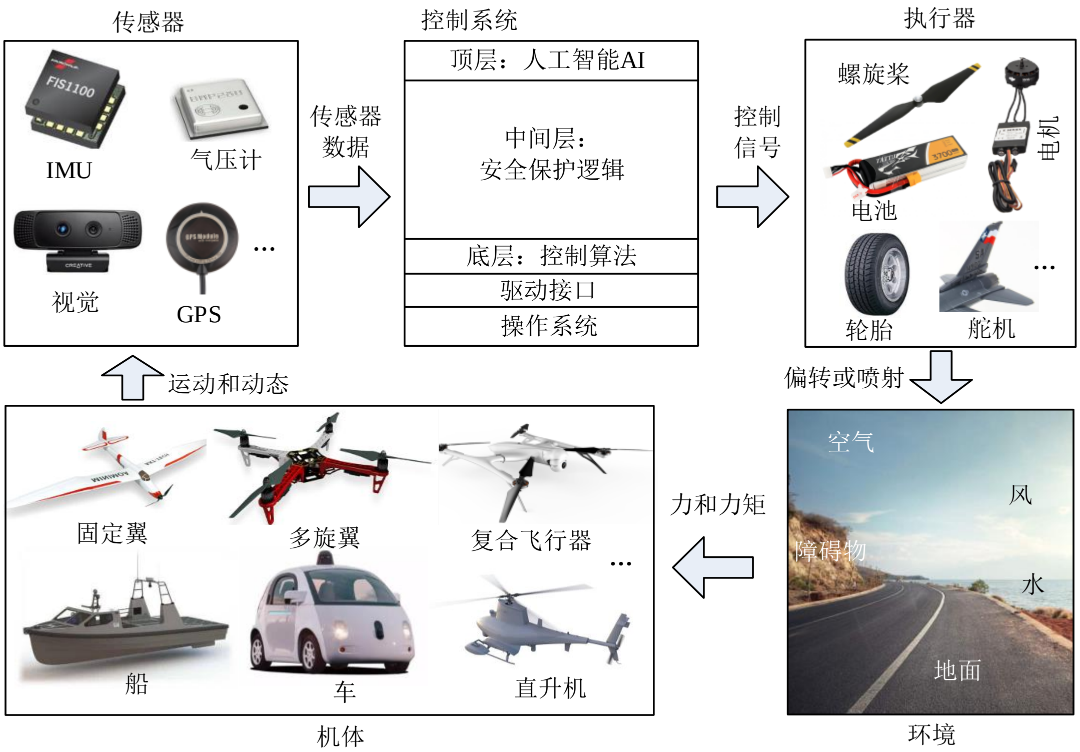
It can be seen from the above process that in the early stage of model design, accurate models of the controlled object and the environment can be established through the study of the whole system, and the controller can be modeled with the control requirements, so that system-level simulation can be realized as early as possible and the dynamic behavior of the system can be grasp - Ed. Moreover, the established object model and environment model can also be reused in other projects, which will also improve the progress of subsequent related project development. To summarize, the advantages of model-based design include:

- In the early stage of the design, multiple system-level simulation verification of the control system is carried out, and the system-level model test is carried out according to the requirements, which greatly advances the exposure time of the problem and reduces the cost of the scheme change in the later stage
- The environment model, object model and controller model established in the development process of model-based control system can be reused by parameter adjustment in other projects, which shortens the model testing time and improves the research and development efficiency
- The model-based development process does not directly depend on the product hardware itself, and the hardware platform can not only realize the algorithm verification, but also effectively isolate the software and hardware faults of the system
- Hardware design and algorithm development can be carried out in parallel, and the research and development cycle of control system is shortened
- In the phase of product implementation, the embedded C code is automatically compiled and generated by the software according to the established specifications. Engineers can spend more time on algorithm design and use case writing, avoid the bugs that may be introduced in the process of hand-writing code, and help to improve the robustness of the system, and finally make the product obtain sustainable competitiveness.

Finally, with the development of automatic code generation technology, the code generated by MATLAB/Simulink and other tools has been able to pass the DO-178B standard, and its readability and reliability have reached a very high level.

The motion model of unmanned system vehicle is modeled modularly

Different types of unmanned systems (such as unmanned vehicles, unmanned aerial vehicles, unmanned ships, etc.) have different shapes and operating environments, but they have many common characteristics from the system structure diagram that can be reused in a large number of modeling and simulation systems. Therefore, the model framework adopts a modular approach to divide the entire unmanned model system into several subsystems, so as to maximize these common factors and simplify the complex modeling problem. At the same time, this approach also facilitates the sharing of the same model between different types of unmanned systems, and can be automatically implemented in model-based design software (such as MATLAB/Simulink). Taking a conventional multi-rotor UAV as an example, its system can be decomposed into a combination of several independent component products, such as motors, batteries, autopilot control systems, remote controls, etc. According to the common system architecture, this modular segmentation method is also applicable to other unmanned vehicle systems.



Modular, component and whole machine process modeling system

The motion model of unmanned system vehicle can be divided into three subsystems through physical and virtual components, including the body subsystem of internal subsystem modules such as actuator, fuselage, operating environment, force and torque. The electronic hardware model sensor subsystem is used to describe all the control software, and the 3D environment subsystem is used to describe the 3D visual environment (including trees, obstacles, roads, etc.) for UAV flight. Each subsystem, in turn, can be subdivided inwards into smaller independent subsystem modules, eventually forming the modular unified modeling framework shown in the figure above.

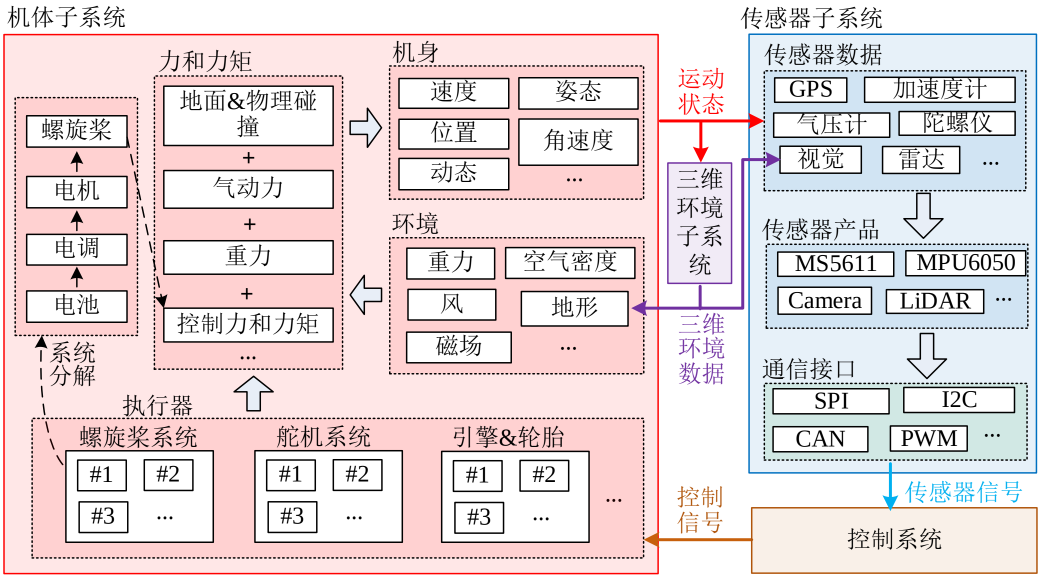


FIG. 2 Unified framework of motion model2

Framework for standardization and certification of unmanned system components

The RflySim platform is expected to build a modeling and certification framework based on digital twin, which aims to improve the development efficiency and certification efficiency of unmanned systems. The core of the framework is a standardized component model, and component suppliers need to certify the provided product component model to ensure that it is consistent with the actual data. Then, unmanned systems companies can use these certified component models to build models in the hardware-in-the-loop simulation system to quickly verify the credibility of the simulation results.

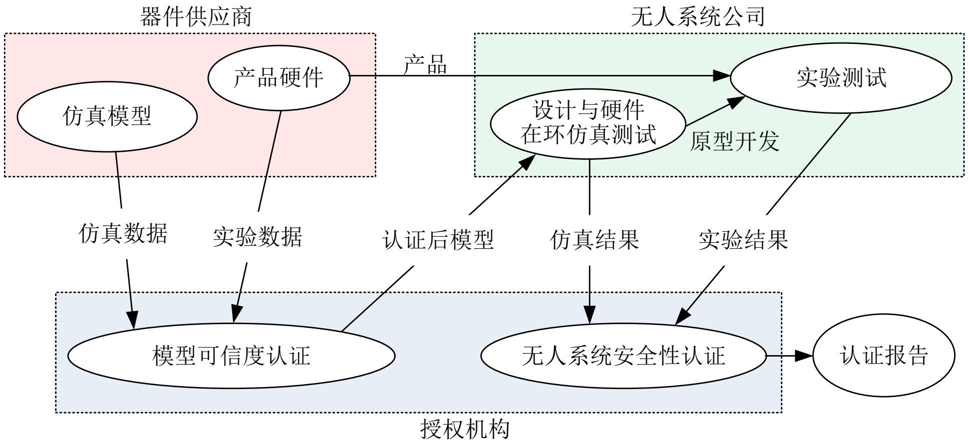
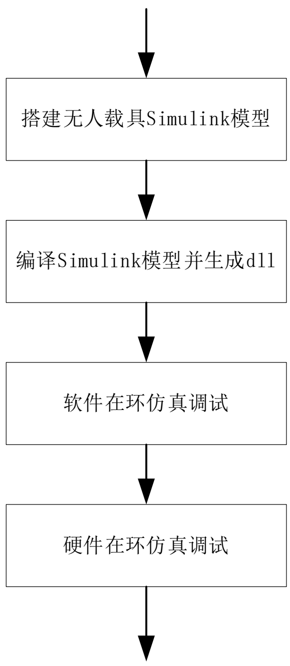


FIG. 3 The certification system under the unified modeling framework3

The idea of process modeling facilitates the rapid establishment o f custom motion models

From the perspective of implementation mechanism, RflySim platform is divided into fiv e parts: motion simulation model, underlying controller, 3D engine, external control and grou nd control station. The platform supports Simulink automatic code generation DLL files, readi ng DLL models, and external interfaces for multiple input and output to help quickly deploy and debug customized unmanned system vehicle models.

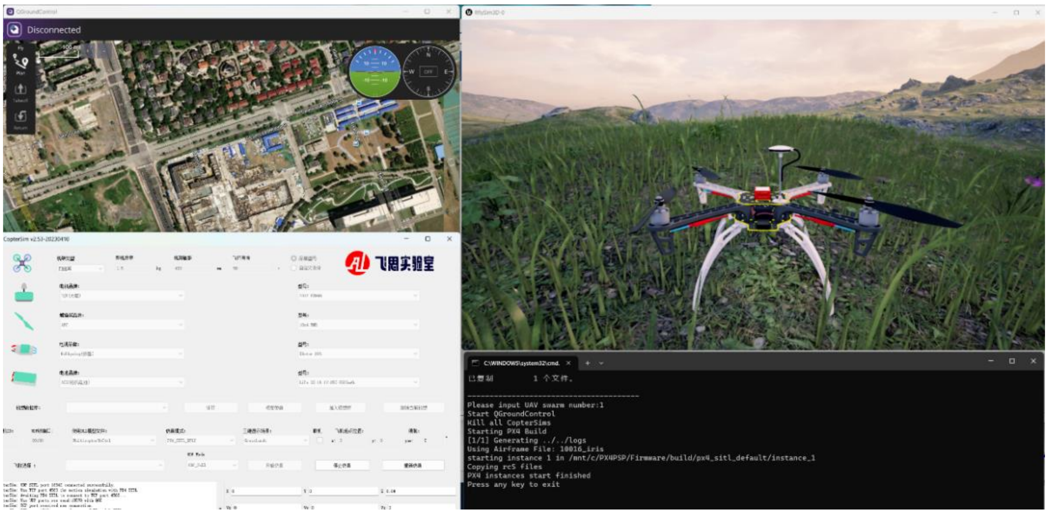


Unified modeling templates are provided

The RflySim platform has two sets of common modeling templates: the minimum syste m model development template contains the minimum required input and output interfaces; The maximum system model development template includes more additional functions, such as collision detection, fault input, custom log recording, flight control and extended data communication functions of 3D engine

Multi-rotor UAV motion model development template

Any multi-rotor model modeling and simulation case can be constructed from sub-models to the whole aircraft through the template of this platform. The only difference between them is that the force and torque of all the rotors are mapped (the projection and summation of magnitude and direction) to the control efficiency model of the resultant force of the fuselage. Without modifying the Simulink model, this can be achieved through the ModelParam_uavType parameter to the computer frame and torque distribution in the platform modeling template. At the same time, to realize different multi-rotor models, it is necessary to adapt the power system parameters and save them into the initialization file.



Fixed-wing UAV motion model development template

Based on the fixed-wing model with minimum input and output interface, the fixed-wing Simulink model was compiled and generated in Matlab to generate DLL model files, and the hardware-software in the loop simulation of fixed-wing UAV was carried out by uploading the route through QGC. The fixed wing model with collision detection is supported, and the control of the UAV can be realized in Offbard mode through the fixed wing position control, attitude control, speed, height yaw control and other interfaces.

Development template of unmanned vehicle motion model

RflySim platform has a refined unmanned vehicle model, and supports different types of unmanned vehicles such as Akaman chassis unmanned vehicles and differential unmanned ve hicles. It has Python and MATLAB two programs for position and speed control interface pr ogram frameworks.

Other unmanned vehicle motion model development templates

With the continuous in-depth development of RflySim platform, it has supported a variet y of motion models of unmanned vehicles, such as vertical UAV, unmanned ship, quadrotor t ail type underwater unmanned vehicle, helicopter and other motion models.

FIG. 4 In-loop simulation rendering of pensile UAV, unmanned ship, and quadrotor and

tail mounted unmanned underwater vehicle4

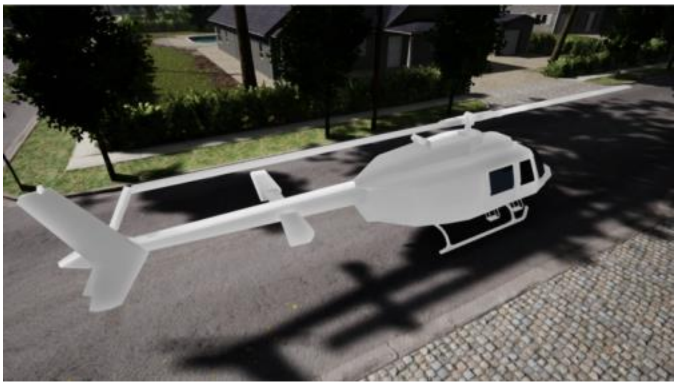


FIG. 5 The simulation effect of the helicopter in the ring5