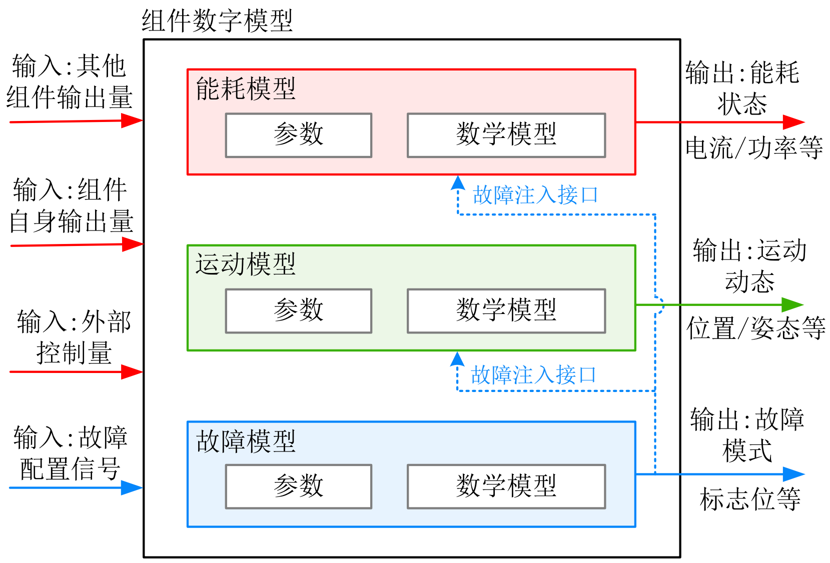
Contents

External control and trajectory planning

Intelligent unmanned system belongs to a typical complex system, and "complex system" generally refers to a kind of system with large scale, complex structure, various functions, various failure modes and unknown and changeable external environment. It often has the characteristics of nonlinearity, dynamic, large scale, multi-level and decentralization, such as the human body, various vehicle systems, precision CNC machine tools and other mechanical or electrical systems, etc. These systems are typical representatives of complex systems. With the increasing complexity of the system, the components and probability of failure will become larger and larger. How to reduce the failure probability and reduce the consequences after the failure, is the content of system health and safety assessment needs to consider.

Unified fault modeling framework

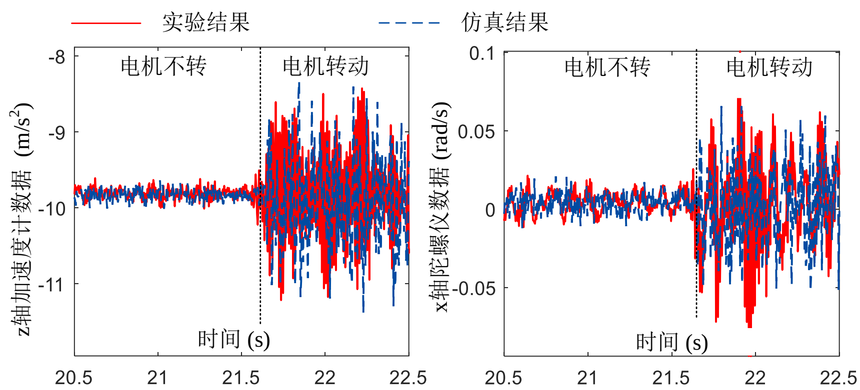
Any unmanned system can be divided into several components (or subsystems), including physical components such as motors, propellers, gyroscopes, and virtual components such as wind, air pressure, and obstacles. Any component can be considered as containing three types of models: energy consumption model, motion model and fault model. The first is the motion model, which is responsible for describing the transient behavior of the component, and the second is the energy model, which is responsible for describing the long-term behavior of the component. The motion model and energy model jointly describe the normal short-term and long-term operation of the component, while the fault model describes the deviation of the component from the normal operation state caused by various internal and external factors.



It supports fault injection for various components of unmanned systems

Unmanned system body fault injection

Airframe faults can be divided into power system faults, energy system faults, sensor faults, airframe structure faults, control system faults and so on according to the topology decomposition and type of subsystems.



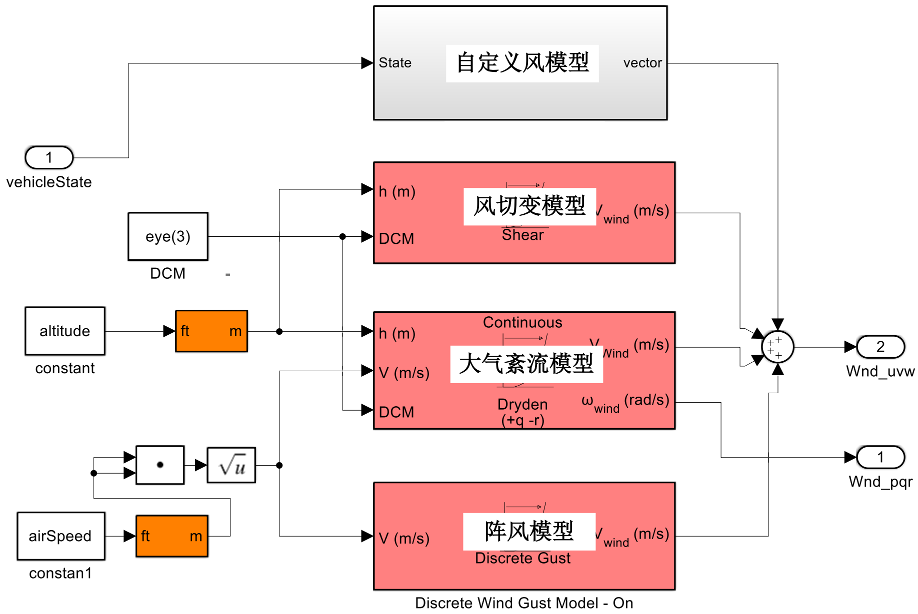
(a) 加速度计噪声和振动数据 (b) 陀螺仪噪声和振动数据

Communication Fault Injection in unmanned systems

Communication failure mainly refers to the abnormal communication between unmanned systems such as remote controllers, wireless data transmission modules, graph transmission modules, and AD hoc network modules or with the ground. It can realize fault injection such as data miscalibration, data transmission interruption, data interference, data error, data interception, cracking, forgery and so on. It can be realized by analyzing the data characteristics of the actual system under the corresponding fault situation, and then programming through discrete or logical methods.

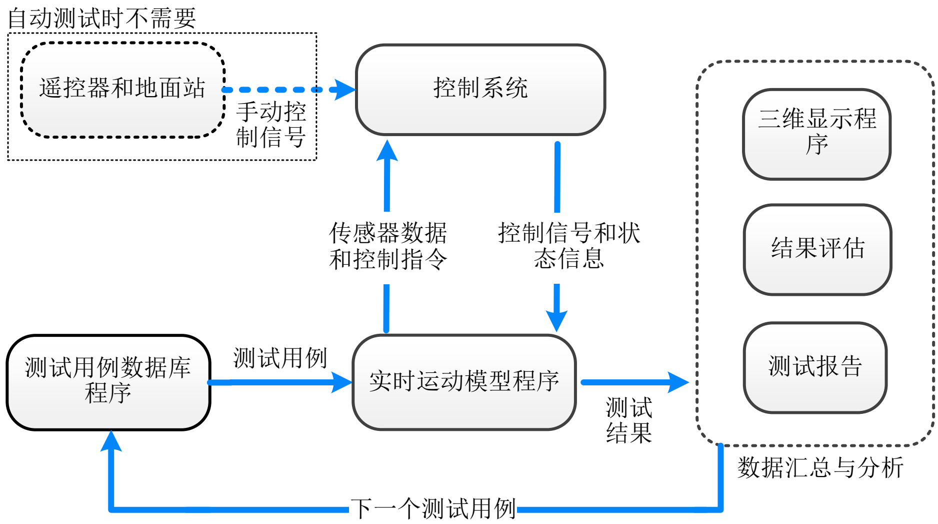
Environmental fault of unmanned system

Environmental failures usually include wind interference, magnetic interference, sudden temperature change, obstacles in 3D scenes or other Uavs, among which wind interference is the most common. The establishment of wind disturbance model is mainly introduced in the following. For example, UAV flying into a complex wind field can be regarded as the superposition of several simple wind field disturbances, including gust, turbulence, wind shear and constant wind.



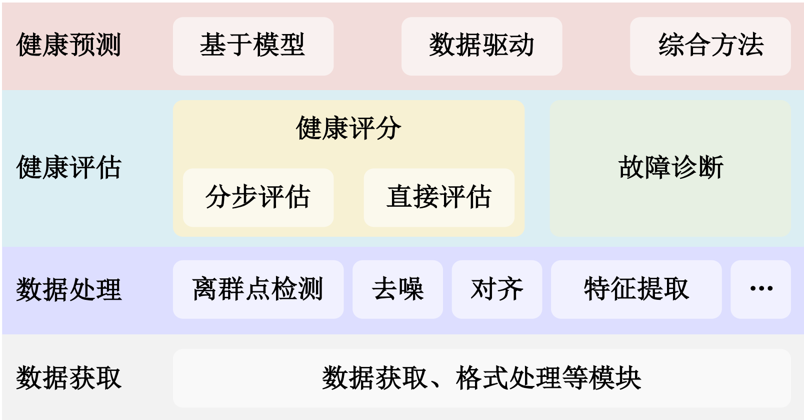
Failure testing and safety assessment framework for unmanned systems

Due to the shortcomings of the experimental method, such as high cost, limited airspace, difficult to repeat, and unable to obtain the true value of the state, it is not feasible to use the experimental test method to obtain the equivalent safety level index. Taking the multi-rotor UAV as a typical example in the RflySim platform, if the experimental method is used to measure the falling speed of the aircraft in a fault situation, it means that each experiment needs to destroy an aircraft, which is unacceptable under the consideration of factors such as cost and ground safety. Based on the hardware-in-the-loop simulation test function of RflySim platform, a fully automated safety test platform as shown in the following figure can be built.

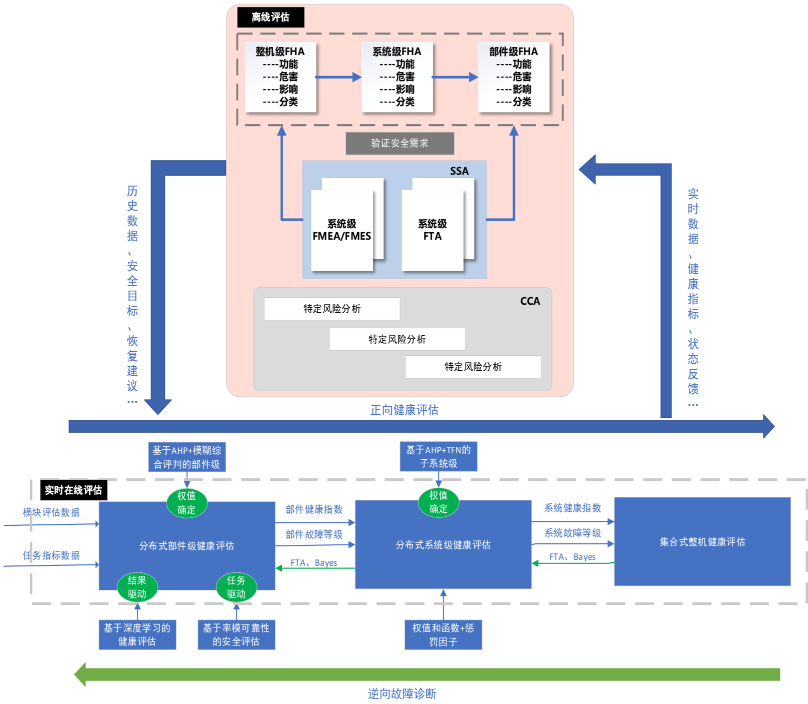


Health scoring and fault diagnosis framework

There is a big difference between the definition of safety of unmanned systems and the definition of safety of manned systems. Therefore, this paper focuses on the definition of safety of unmanned systems and the extension of safety assessment methods. As a typical complex system, there is no essential difference between the definition of health of unmanned system and the definition of health of manned system, but unmanned system is more complex, and there are usually more factors to consider, and the process is more complex.



The RflySim platform firstly does offline assessment, establishes a preliminary failure mode and impact analysis table, and a historical database. Secondly, according to the output of the offline evaluation, the real-time online evaluation is done. After a flight mission, the real-time data is collected, and the health indicators and safety status of each subsystem are updated to the failure mode and impact analysis table and historical database.



Distributed component-level health assessment

The weight relationship between the component level is determined by AHP (analytic Hierarchy process) and expert experience, and then the health score of each component is evaluated according to the deep learning method, and the health score of each component is output. The impact and degree of failure are quantified by the safety assessment method based on rate modulus reliability, which is used as the input of the subsystem level health assessment.