

## DESIGN OF UAV SIMULATOR BASED ON MAN-IN-LOOP SIMULATION PLATFORM

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**Abstract:** As the UAV is widely applied in military action, in order to make the UAV operators operate the UAV equipment easily, we should train the UAV operator with high efficiency, high fidelity training system, which can be used in the training work in stead of the real UAV aircraft. It can heighten the training efficiency and reduce the training cost. We put forward the design project of the man-in-loop UAV flying simulator based on Matlab/Simulink, according to the flying control system's characteristic and the request of the man-in loop simulation. Compared with traditional program in manual, the modeling design base on Simulink has the characteristics of agility, speediness, high efficiency and few cost. it can will do help in the design of UAV training simulation.

**Keywords:** Unmanned Aerial Vehicle (UAV); Simulation Training; Man-in-loop; Simulation Platform; Application.

### I. INTRODUCTION

With the development of aviation and electron technology, the function of UAV is increasing, thus made the flying control system is getting more and more complicated, thus the malfunction risk for the UAV equipment is getting big, in order to make sure that the UAV operator can operate the UAV's flying safely and efficiency, we should do much work in the simulate training to increase the training fidelity and efficiency. Therefore, simulate training play an important role in daily training of the UAV [1]. For these requirements, the fast establishing of the simulation system of UAV is a problem should be put forward; Matlab/Simulink tool can be applied as assist platform to this problem. This method can reduce the employer training periods and avoid the faults produced by manual programming.

## II. HARDWARE-IN-LOOP SIMULATION

System simulation technology is based on resembling principle, information technology and system technology. It relies on computer and other physics equipments, which adopts simulating modeling in the research system and related experiments. The simulation technology provides us an method to do the scientific research, problem analysis, decision making, and designing for the professional researcher. It can improve the cognitive ability for people and also can promote the rational analysis ability in science [2].

Hardware-in-loop simulation technology is developed with the development of army equipment research, training system design and computer technology. The actual military experiment always to be expensive. Hardware-in-loop simulation technology offer us the great value method in the weapon system experiment and simulate training. In other words, we can test the weapon performance in entire life-long, so it can reduce the research periods and the training cost. Therefore, the key research technology of hardware-in-loop simulation system will bring the great value for the army.

Compare with the other simulations, hardware-in-loop simulation has great authenticity, it is a reliability simulation method, in the view of system, the hardware-in-loop simulation system permit the actual object in the loop, so it means that we can check the object performance in the loop, in this way the whole capability of the system could be detected in the simulation loop, therefore, hardware-in-loop simulation is a good simulation for system experiment.

## III. MAN IN LOOP SIMULATION PLATFORM

### 1. Analysis and presentation of man-in-loop simulation platform

UAV training system usually adopts mathematics modeling to replace the real aircraft, in this way we can use the mathematics modeling instead of the real airplane, the control system and dynamic modeling are designed in mathematics simulation environment, we can contrast the flying parameter in mathematics model with the parameter in actual flying environment, if the dynamic flying data generated by the model have much variance with the real flying data, it can conclude that the flying modeling is not true or flying modeling is not precise, and

then we should design the dynamic UAV simulation model and compare the simulation output data again, repeat the process while the simulation data is accordance with the actual data. The software of Matlab also provides the RTW, XPC toolbox, it can generate the embedded code in time. We can apply the design idea in the production of the UAV.

Because there are objects in the simulation loop, so the time measurement of the simulation should as long as real time, in other words, hardware-in-loop simulation must work in real time [3], as simulation computer is connected with real object, so the simulation system must acquire dynamic parameters and export dynamic response in real time.

Simulation step must include two aspects: first it should insure that simulation modeling must work in real time; second it should insure that simulation step must simulate the real signal's characteristics [4].

## **2. UAV Modeling compared and select base on Matlab platform**

Matlab is an scientific computational software, which contact the numerical value account with the videotext, What offer abundant internal function, therefore matlab is widely used in scientific computation, control system and information management. In the past 20 years, it has been the most popular computational software in the world.

Control system model added with UAV flying dynamic model which is based on Matlab/simulink hardware-in-loop simulation system, can reduce the time of system design and the work of arithmetic calculations. This simulation technology is open and can be accepted. It can make different equipments work on a same platform. In this way we can provide a simulation environment in developing more function for the system.

Matlab environment platform have three styles modelings according to object characteristics: M-file, Simulink-block and S-function [5].

### **(1) M - file**

M-file using user-defined expression structure by itself, which is readability for C programmer and it comprises abundant internal functions, however, every step of calculation could be done by Matlab, thus reduce the efficiency of the modeling, the mode can not be used in the simulation system, which needs simulate in real-time.

## **(2) Simulink-block**

Simulink block is a dynamic interaction environment which can afford us dynamic modeling, simulation and analysis. In the method, the non-linear factors and stochastic factors are not considered. In the environment of simulink, the modeling can use differential equation to describe the dynamic characteristics, the user can operate mouse by hand in stead of write programe in text, which can establish visual simulation modeling [6].

Simulink contains many basic modeling such as aerospace module and so on, aerosim toolbox is aim at UAV simulation researching, we can make use this toolbox in the simulation analysis.

## **(3) S-function**

S-function comes from the C program according to mex-file style, which can compile and link by Matlab compiler. At last, it can form .dll file which can transfer in Matlab environment, which can heighten the efficiency of programme. S-function has the characteristics of readability and modification.

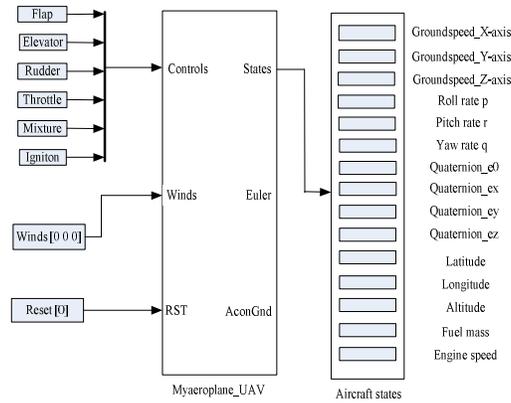
Compare with three modeling methods in Matlab and the simulation system designing. Speed design of the dynamic simulator is mainly used for daily training. According to performance of each method, the simulink modeling has high efficiency, function distinguishing, module modify and implement simpleness, facility maintenance and expand. Which can adapt to simulation modeling of UAV training system, so in the paper, we adopt simulink block in dynamic modeling design of the training system.

# **IV. DYNAMIC SIMULATION MODELING FOR UAV**

## **(1) Flying Simulation block file configration based on Aerosim tool box**

Simulink have many functions about dynamic modeling, which are related to other high level programming language (such as C language), it has mightiness calculating ability, and can operate easily and maturity module and in the modeling it can be translated into real time code. Simulink has many toolboxes in engineering application, includes aerospace for aircraft flying simulation, if we adopt these toolboxes manpower and time can be saved. Because Matlab is exoteric, there are many plugins could do help for our own project, we

could use these basic module to set up the complete six degrees freedom aircraft model, some models are not modify or needs a little modify for using in our project, such as atmosphere model and earth model, as shown in Fig. 1.



**Fig.1** Complete 6-degree-freedom aircraft modeling and internal structure

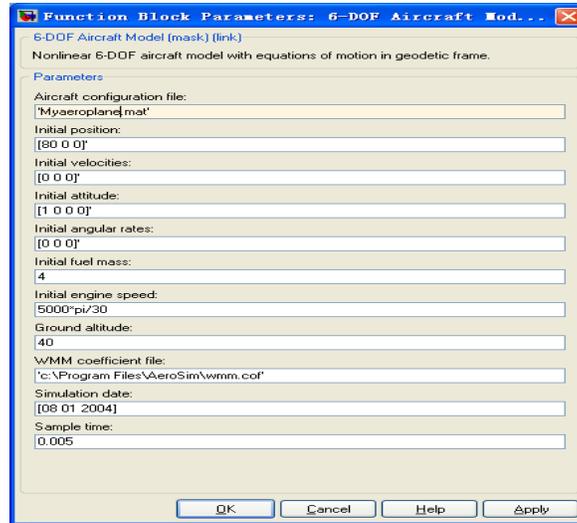
The Aerosim aeronautical simulation blockset provides a complete set of tools for the rapid developing of nonlinear 6 degree of freedom aircraft dynamic models. In addition to the basic aircraft dynamics blocks, the library also includes complete aircraft models which can be customized through parameter files [7].

A new aircraft parameter file can be generated from a custom Matlab script. In order to create this script, we need to open the template aircraft configuration script `config_template.m`, which specifies the aircraft aerodynamic, propulsion and inertia parameters. By running this script at the Matlab command prompt, a new aircraft parameter file of the form `filename.mat` will be created. The file name then can be used in any of the complete aircraft blocks available in the Aerosim library. The first variable that should be specified is the name of the aircraft parameter file that will be generated. Type the chosen name of our aircraft parameter file, as a string, without the `.mat` extension [7]:

```
% Insert the name of the MAT-file that will be generated
```

```
% without.mat extension
```

```
cfgmatfile='myairplanecfg'
```

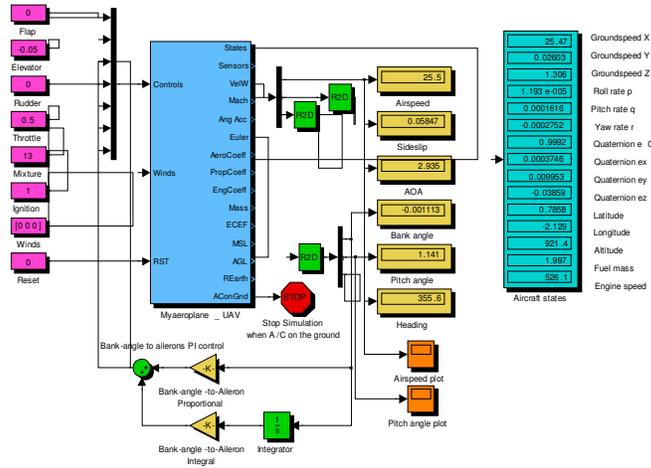


**Fig.2** UAV parameters configuration dialog

Next we double-click the block to open the block parameters dialog. As Fig.2 is shown, we can specify the aircraft parameter file—Myairplane.mat, the initial conditions (position, velocity, attitude, angular rates, fuel, engine speed), the ground altitude according to the sea-level, and the simulation sample time.

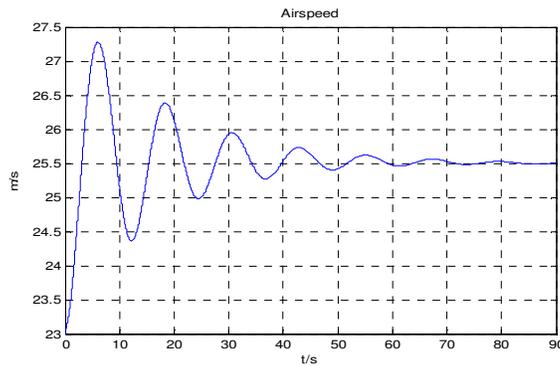
## (2) Design and analysis UAV simulation modeling

We can construct the modeling through Aerosim toolbox, before starting the simulation, we can also add a constant source for the controls input to the aircraft model. This will provide the model with a set of constant actuator commands. Finally, we can use the simulink model pull-down menu, under simulation and open the simulation parameters. Set the solver type with fixed-step, the integration scheme to ode-4 or ode-5, and set the fixed-step size to match the aircraft model sample time. The simulink model diagram is shown in Fig.3.

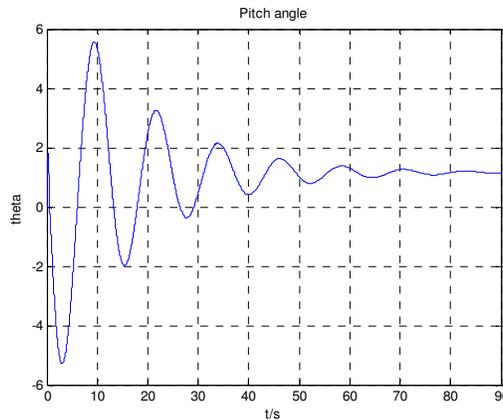


**Fig.3** dynamic simulation of UAV block diagram

After the commands is given to the intergrated UAV modeling, the simulation modeling starts to calculate the UAV state according to the simulation time span and simulation step. The airspeed depends on the elevator setting. The model adds an airspeed control loop using PID (proportional, integral, derivative) control laws.



**Fig.4** UAV Airspeed outputs



**Fig.5** UAV Pitch angle outputs

By running the simulation, we could see a plot of the air speed and pitch angle as shown in Fig.4 and Fig.5. The airspeed does approach the set value about 25m/s, while the oscillations are virtually eliminated and the pitch angle settles with the value of approximately 1.7 degrees.

## V. CONCLUSION

In the paper, we introduce a project designing for man-in-loop simulator of UAV training system. Compared with three methods in Matlab platform, we adopt Aerosim toolbox to make up the whole dynamic simulation model. Emphasis of the designing process and flying parameters file configuration are obtained. We find that it has the feasibility and advantage in the designing course base on Simulink/Aerosim toolbox. We should configure parameters file and make .mat extension file. Since the integrated modeling is set up, we can use real-time-workshop in generating source code from our aircraft models automatically. Thus the source code from models could do the foundation work for our fidelity training simulator of UAV.

## REFERENCES

- [1] Anonymous, current and future UAV military users and applications, Air & space Europe, 1999, 1(5/6).
- [2] Jiang yu-xian, Zhu en, Control system and simulation, Beijing, Beijing University of aeronautics and astronautics publishing company, 1998.
- [3] Xiao tian-yuan, Zhang yan-yun, System Simulation Introduction, Beijing, Qing hua university publishing company, 2000.
- [4] Yang cheng, Du guo-ning, Real time simulation system design base on Matlab, applied of micro-computer, 2003, 19(3).
- [5] Jing zhen-yi, Zhang ze-bing, Banausic manual of MATLAB7.0, 2008, 12.
- [6] Bi kai-bo, Wang xiao-dong, Flying navigation, controls and MATLAB simulation Technology, 2009.
- [7] Information on AeroSim block user's Guide. [http://: www.u-dynamics.com](http://www.u-dynamics.com).