

The Application Research of Aircraft Simulation System for Speediness Prototype and Integrative Modeling

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Abstract

For solve the problem of flight simulation system accurately modeling, speediness and high efficiency implement. It brings forward flight simulation system of aircraft speediness and integrative modeling method based on Aerosim/RTW. Compare with traditional development method for flight simulation system, the method that based on Aerosim/RTW could implement speediness prototype and integrative process which from digital simulation model establishing to system implement. Lastly the simulation results showed that: this technique based on Aerosim/RTW could achieve speediness prototype and integrative construct for aircraft dynamic flight simulation system and give birth to remote sensing of flight data flow. The technology has simpleness, convenience and high efficiency characteristic in the course of constructing for the flight simulation system of aircraft.

Keywords: aircraft, high efficiency modeling, Aerosim/RTW, speediness and integrative

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1. Introduction

The flight simulation system is the core of Aircraft simulator, it could achieve most function of the aircraft. The pilot can operate flight simulation system to accomplish the flight training task and it could reappear the complicated flight environment in the air, so the flight simulation system should reappear the real equipment of aircraft by reality and nicety for who is flight in the air. The fidelity training simulator could save training cost, for training safely and without field limited [1].

Traditional technology of the aircraft simulation system designing is lack of speediness and high efficiency. Along with the modern simulation technology is developed, time and efficiency factor play more important role in the practical project. So "speediness prototype and integrative" technique is become one desiderate solving problem in the fields of flight simulation, Matlab/Simulink simulation platform and its correlative toolbox could offer us technology support for this problem. The purpose of speediness prototype and integrative for flight simulation system is to do the simulation work for whole course and full time of flying. Which could achieve the integrative modeling process from the simulation system construct to the software operation by accurately and high efficiency [2].

So it has abroad application foreground in the flight simulation fields. which using Simulink/Aerosim toolbox to set up 6 degree of freedom and full variable kinematics equation for aircraft, it could set up flight simulation system by speediness according to specify aerodynamic layout aircraft, then accomplish all "dummy" flight course, it make operation code from flight simulation model in the real operating system by RTW, which build implement programme by software and hardware environment of target system, it can accelerate the designing process of the simulation system. So "speediness prototype and integrative" technology have important academic study meaning and application value.

2. Flight Simulation System Development

2.1. Flight Simulator Brief Introduction

Study on flight simulator could benefit us for daily training work, flight simulator is an typical application instance for modeling and simulation technology. It's not only have gained perfect training effect by fidelity simulation training work, but also have much advantage characteristic such as safety, convenience, without environment limited, low cost and reuse. Fidelity flight simulation training could shorten the training periods and advance flight skill for the pilot. Generally the flight simulator include visual display system, kinematics system, sounds system, operation loading system, all of which formed an visual flight environment in the ground, it can repeat real flight course in the air and the troubles possibility appeared, then offered to the pilot fidelity visual display, operation, sounds and kinetic sensing. The typical flight simulation training system is shown as Figure 1.



Figure 1. Full Mission Simulator of F-35 Fighter

From recently research status, the flight simulator have to be an important tool for airplane designer, test pilot driving, pilot, navigator and ground crew at airport to do the flight training work and experimental study. Which have much advantages such as low cost, high fidelity and reliability, flexible, abroad application and strong practicability. It have show gigantic advantage in training pilot, enhance pilot to adapt the variational ability, ensure the aeroplane safely flying, enhance the army's battle effectiveness, reduce the outlay for scientific research and training.

2.2. Flight Development Mode for Flight Simulation System

Generally the flight simulation system include many subsystem, each subsystem have some modules, and there exist complicated relationship between each subsystem. So it's hard to construct a reasonable framework, software and hardware platform for easily implement, so we should research on the structure and blocking function, data working flow and simulation software development technology. After full and integrated consideration, we should choose one engineering method with simple, practicality, low development cost and short periods.

At present, the flight simulator have 3 mode: ① Course-Oriented simulation system development method (the traditional Oriented Course C language, Fortran language and assembly language); ② Matlab/Simulink simulation system development method; ③ Object-Oriented simulation system development method (based on Visual C++ development environment).

In the designing process, the generally method include: firstly, make use of Matlab/Simulink toolbox to validate theory which bring forward, then adopt computer language (such as assembly language, C or C++ language) to achieve the whole simulation system by handwork, make .exe file (perform module) in personal computer, lastly build executable program module. The disadvantage of this method is that which has long development period and low development efficiency, and because of programme by handwork could make different with Simulink module, thereby it could effect the consistency for whole system. As computer technology make progress, RTW (Real-Time Workshop) tool could build executable code which

have not different with program by handwork, what offer a perfect solving method for this problem.

It is adapt to research and design the flight control rate and flight control system based on Matlab/Simulink tool in the initial period, which could do some hardware in loop simulation experiment with low cost; to construct the simulation system based on Object-oriented have much advantage about blocking, expansibility and repeat using, it could construct the whole simulation system based on unified operation framework, which have maturity development environment (Visual C++ development environment), but this development method have some disadvantage about long development periods, professional technology about Object-oriented software development, which is not good at speediness prototype and integrative to set up the flight simulation system.

2.3. Development Method for Speediness Prototype and Integrative

“Speediness prototype and integrative” presumed that it establish the simulation system by speediness at initial stage, and then do the simulation experiment in this simulation platform we can development simulation model and algorithm, then which could validate rationality and applicability of the software and hardware designing project, it accomplish code generation by automatic and downloading in late stage, finally achieve the system designing process. It bring forward “Speediness and prototype” idea in the 90s of 20th century, which could accomplish the modeling and simulation work which from concept to production, it obtain a visual product, do the demonstrate and validate work for function, performance, indicator and markets, we can modify the project by speediness according to feedback information, the establishing model and document in middle stage is foundation of product designing [4]. “Speediness prototype and integrative” is based on speediness prototype and pay more attention to “whole process and prototype development” from the function demand to production molding.

Speediness prototype and integrative have much advantage in reducing research periods and development cost, many research institution put forward “speediness prototype and integrative” real-time simulation platform. For example, dSPACE company from Germany develop dSPACE, Mathworks company develop xPC, Opal-RT from Canada develop RT_LAB[5]. The system’s structure, principle and prototype designing flow which all basically support the Matlab/Simulink software, and almost all framework adopt mode about “host computer to target computer”, the host computer adopt Windows operating system, which is using to develop mathematics model, target machine adopt real-time computer, it install the real-time operating system and could do simulation operation working.

Aerocraft simulation system speediness prototype and integrative is according as the working principle of flight simulation system, data flow and then using speediness prototype and integrative platform, which adopt Matlab/Simulink software to modeling, and then achieve whole process from model designing to real-time product testing and development course [6]. Flight simulation system speediness prototype and integrative development flow chart is shown as Figure 2.

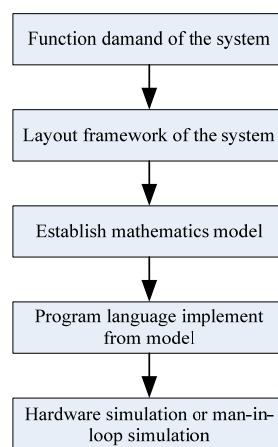


Figure 2. The Flow Chart for Aerocraft Simulation System of Speediness and Integrative

Traditional development flow chart for flight simulation system include 5 parts: ① Confirm the function needing of the system, then confirm technique and tactics indicators; ② Make out structure frame for the system, designing control algorithms; ③ Establishing mathematics model of the system, doing simple digital simulation at initial stage by Matlab/Simulink toolbox; ④ Achieve program language for the mathematics model by C or other program language; ⑤ Semi-physical simulation or physical simulation, then perfect simulation model designing and control algorithm. The workload is much more and the time is consuming step is ④ and ⑤, which request to operate the simulation model in detached environment (Matlab/Simulink development environment). In the process of program language implement which using C language or C++ language, the workload of program is much more and it easily to make mistake, then we should consider about some problems which is in computer fields such as interface relationship, data switch and timing interrupt. Generally the simulation program has not on line modified function, so it need costly watcher equipment, which should consume more outlay.

Traditional development method for the aircraft simulation system is not benefit for play down the cost, but “speediness prototype and integrative” could achieve prototype and integrative process such as modeling analyse, model programme, automatics code build and download. This process adopt open framework, it could shorten development periods and heighten reuse. So study on the new development method have important value to the aircraft simulation system establishing accurately. Personal computer’s performance has development very fast at present. Compare with traditional special simulator which has high cost, no exoteric framework for software structure, upgrade and maintenance is not convenience. Matlab software based on PC has become development trend [7].

3. UAV Simulation System Modeling Project Based on Simulink/Aerosim

3.1. The Structure Frame and Operational Mode for Flight Simulation System

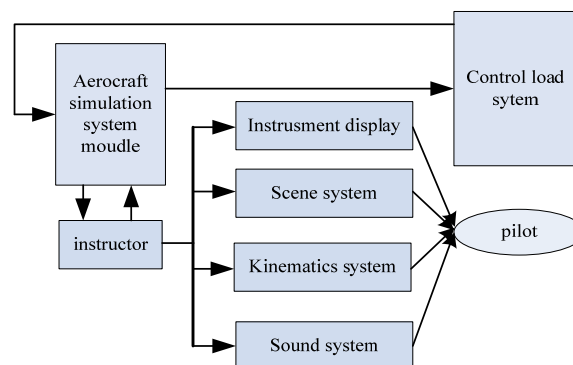


Figure 3. The Compositive Structure Chart of Aircraft Simulation Training System

“Simulation model” is the core of the simulation system, generally it using the flight simulation model in personal computer instead of “aerocraft system”. Which is a complicated simulation system, and generally it comprise a lot of mathematical models.

The aircraft simulation system in the project is using for pilot training, so the simulation model should reflect the essential character. of the aircraft system. Training flight simulator is using for pilot and others aircrew’s simulate training and professional skills training. So the simulation training equipment which manufacture should according with the environment consistent, dynamic consistent and information consistent principle, which could do the fidelity simulate working for flight dynamic, flight altitude and physiology feedback for human, then show that the seeing, hear, smell and feeling from the pilot, thereby which could acquire perfect training effecton [5]. The flight training simulation system have much advantage such as economic, safely, no-limited for fields and weather, shorten training periods and enhance

training efficiency [6]. Especially for some dangerous training subject and flight accident which is not easily to deal with, all of which could accomplish in training flight simulator.

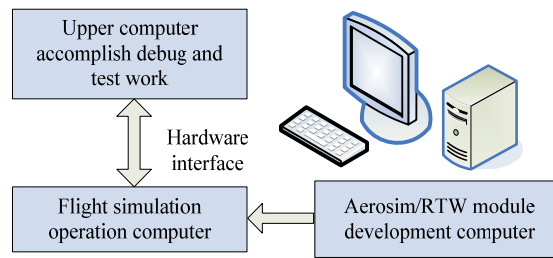


Figure 4. The Framework Chart for the System

The designing project of simulation system adopt signal computer mode(personal operation mechanism). This mode is very adapt to the training system. The framework chart for the system is shown as Figure 4.

3.2. Development Flow Chart for the Simulation System

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2, 5]. The discussion can be made in several sub-chapters.

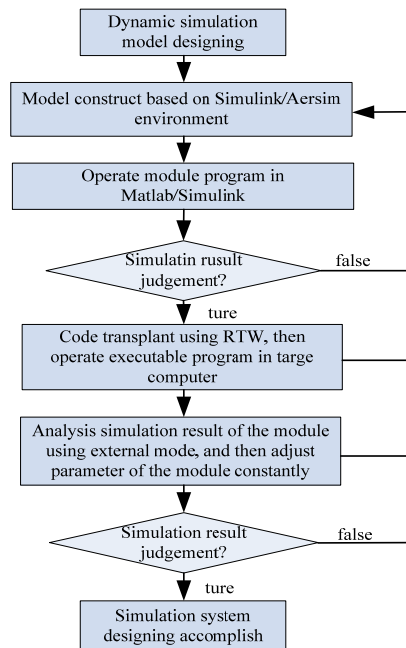


Figure 5. Development flow chart for the flight simulation system

Simulation system speediness prototype start with Matlab/Simulink. Firstly setting up the flight simulation system object model (aerocraft simulation model), and then using Matlab/Simulink toolbox to development mathematical module and analyse simulation result, if the simulation result is not satisfied, we should rebuild the simulation model, unto the simulation result is satisfied. Once obtain perfect simulation result, we could generate transplntable C

code from simulation model by RTW toolbox. It could adjust parameters and optimize module structure which adopt external model of the simulink, it afresh obtain the simulation result, at this time, it come into product manufacture stage, transplant the simulation module into the real-time control system. The key of speediness prototype is automatic building, it make the algorithm code producing by automatic, and comprise C code compile links and transplant it to the target hardware [8]. The development flow chart is shown as Figure 5.

3.3. Development Method for Speediness Prototype and Integrative

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2, 5]. The discussion can be made in several sub-chapters.

Matlab/Simulink is an powerful and dynamic modeling toolbox. Compare with other advanced computer languages(such as C language), it have strongly computational function, programme and operation is simple, module abundant and can be reuse, it could transplant real-time code by high efficiency. Simulink has abundant toolbox in engineering application, for example Aerospace toolbox, make use of this toolbox we can save much time and manpower. At the same time Simulink adopt framework diagram style, it is conveniency for designing dynamic model. Because of Matlab/Simulink have opening, so it comprise many high efficiency plug-in, Aerosim is a integrated no-linear 6 DOF flight dynamic and kinematics module which offered by Unmanned Dynamics company. Using and modify the user module according to the specifically blocking, and then combine this simulation module according as data flow, in the end we can accomplish integrated dynamic simulation model. many modules can be using with no modify, such as atmosphere model blocking, earth model blocking and so on. The interior structure of the aircraft dynamic simulation model is shown as Figure 6 [9].

Project adopt Simulink/Aerosim toolbox to establish the dynamic simulation model for aircraft. Aerosim is a nonlinear 6 DOF integrated flight dynamic tool module who offered by Unmanned Dynamics company, it can be setting each parameter by configuration file which is in system install folder.

There has being an Config_template.m file in the install directory who named Sample, the user could gained special aerodynamic airplane through modify the interrelated parameters of aircraft in this file, the file in project is named MY_Aircraft.mat which showing at right of Figure 7 who should filling into the Aircraft configuration file, aircraft initial module and parameter value's setting is shown as Figure 7.

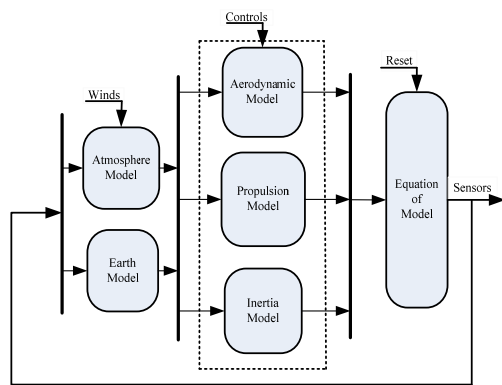


Figure 6. The Interior Structure for Flight Simulation Model

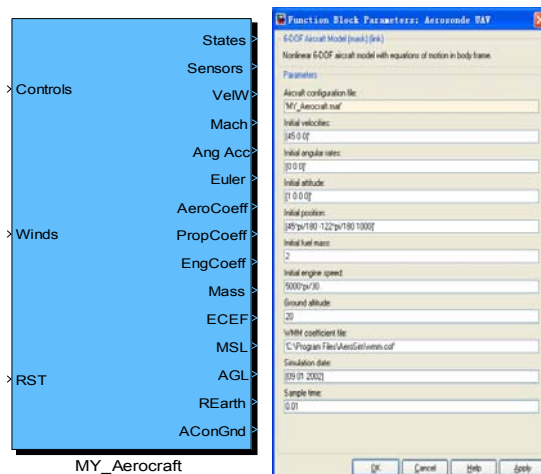


Figure 7. Aircraft Module and Initialize Setting

Each module in Aerosim is composing by the basic module of simulink, and it also offer integrated aircraft 6 DOF flight aerodynamic simulation model module, user could make use of

RTW(Real-time Workshop) build real-time code by automatic according specific target computer. The initial parameters of aircraft is showing as follows:

Aircraft configuration file: this file is using .mat as extension, the needing produced file with .mat as extension whoes default file name is template_cfg.m, project modify this file name as MY_Aerocraft, this file adopt .m as extension, operate this file in the Matlab command window, then we can gained the same name file with .mat as extension (when operation the file it should not with .m extension). In this process we can transform .m file to .mat file, then put the MY_Aerocraft file into the configure file dialog box which is shown at right of Figure 7.

Through modify the flight simulation parameters and setup initial parameters, we can customize special aircraft for different aerodynamic layout, and then do simulation calculation according as the initial value's setting.

4. Real Time Programme Build Method for Flight Simulation System

Traditional flight simulation system in the flight simulator commonly adopt closed development mode, each given aircraft need special control software, which have not modern flight operation system. The modern flight simulation system request that real time embedded type operation system in essence. With flight control task is increasing and complicated control ratio has been used, the development method for the traditional flight simulation software has faced some problems with low reliability and feasibility.

4.1. Development of RTW and Environment Configuration

RTW (Real-Time Workshop) is an important expanded function for the simulink which is a modeling simulation environment who based on graphics, it is a source code creating environment and could build optimize and transplantable source code from simulink, then build real time program according with target computer [10]. RTW sustain multi-type prototype target computer, it could make simulink model directly into the real time programme which is running in personal computer.

RTW is a toolbox which is using together with Matlab/Simulink, it can build real time code from simulink model and establish different operation program in different operation environment. This environment include: real time system and single computer simulation environment. RTW have aboard applied occasion: convenient C code, it could build the following code according to user's setup [11-13]:

① Ada code: it build Ada code from simulink model, which need user to install Real-Time Workshop Ada Coder.

② Real time program: transform the code into real time program which adapt hardware system, corresponding code is connected with a external clock and operating by a fixed frequency which is setting by the user.

③ Signal computer simulation program for high performance: use the code together with real time system target file, make executing program for the signal computer simulation. RTW user's interface could offer a simulation parameters dialog box, open up the dialog box, Real-Time Workshop page only do effect for the Real-Time Workshop, and others page could do effect for both simulink and Real-Time Workshop.

Make use of RTW could build high quality and transplantable code which from continuous system, discrete system and mixed system, it could produce program by automatic and the course is all roboticized. Through make file to establish the target file and transplant it to the hardware by self-acting, Parameters from simulink to external hardware could rectify in on-line mode. It is very simple of Simulink/RTW, and the mainly work is setting the solver as fixed step, then select appropriate algorithm and calculational step.

4.2. Real-time Simulation Program Producting Method

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

RTW programme setup process by automatic could build rea-time applied programme in different host computer. This process adopt multi-binging applied program in advanced computer languages compiler to control the course for building source code's translate and

links. RTW adopt M language order to control the build course, the default order is named `make_rtw`, this establishing process generally comprise 4 step:

- 1) Model analysis
- 2) Target computer language compiler build code
- 3) Build multi-translate file(make file)
- 4) Build executable program

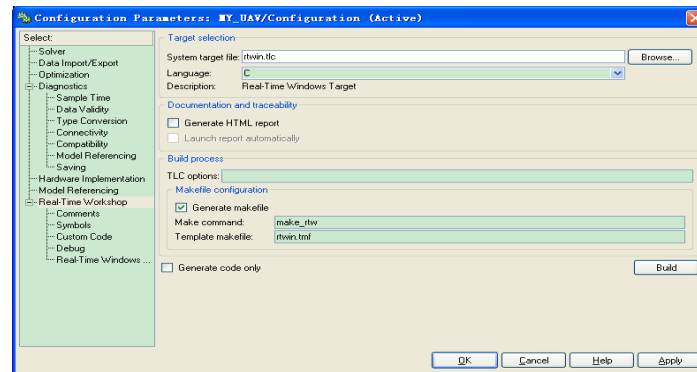


Figure 8. Parameters Setting Dialog Box

After setting the compiling environment, it adopt Tool | Real-Time Workshop | Build model menu to do the compiling and link work, finally build the executed file [14-15].

It could generate accurately and high efficiency executable code in the personal computer which using RTW with speediness and prototype, and this method could shorten the development periods. Making use of speediness and prototype tool could setup the simulation parameters, its not need traditional code write process and then it build executable code in personal computer by automatic. Open Simulink/Simulation/Configuration Parameter to setup the simulation parameters. The key of this setting process is to correctly configure Solver and make real-time RTW (Real-Time Workshop) option. Solver option: setup "Stop time" as inf; stepup Slover as fixed-step, RTW only make code from the fixed-step; "Slover setup" as "Discrete" [16-18].

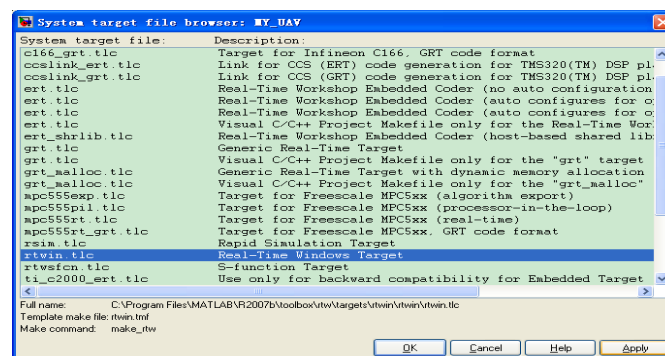


Figure 9. Real-Time Tools of Target Choose Dialog Box

RTW could build C code by automatic from simulink model, so it should correct the given system target file and template makefile. It's name is "rtwin.tlc" and "rtwin.tmf". After setup the building option, then click the building button in RTW template. Matlab could connect with CCS by automatic, start up system target file and transform the flight simulation system diagrams to the executable code who's name is `rt_MY_aerocraft`. It mainly include: source

folder, library folder and connect file. It is showing all detailed manage course in the background of Matlab command window. In the process of code building it need to modify system model according to inaccurate report. Click Browse button of the system file which is showing as Figure 8, it could appear real-target dialog as Figure 9, then we can select the anticipant type target file, in this project it is rtwin.tlc, namely Real-Time Windows Target type.

4.3. Example for Simulation Results Analysis

Contrapose typical aircraft system (given aerodynamic layout aircraft) to construct flight simulation model which is shown as Figure 10, study on the perfect environment (Wind[0 0 0])and wind environment (Wind[x y z]) of aircraft typical parameters (airspeed and 3 typic Euler) output, which could explain the feasibility and validity for this constructing simulation system.

The parameters setup file for this aircraft is naming as Airplane.m, running this file in Matlab command window (without extension of .m), then it could build Airplane.mat file, put this file into the parameters configuration option which is shown as Figure 7, at this time each parameter of the aircraft would go on with initial value according to this setting file.

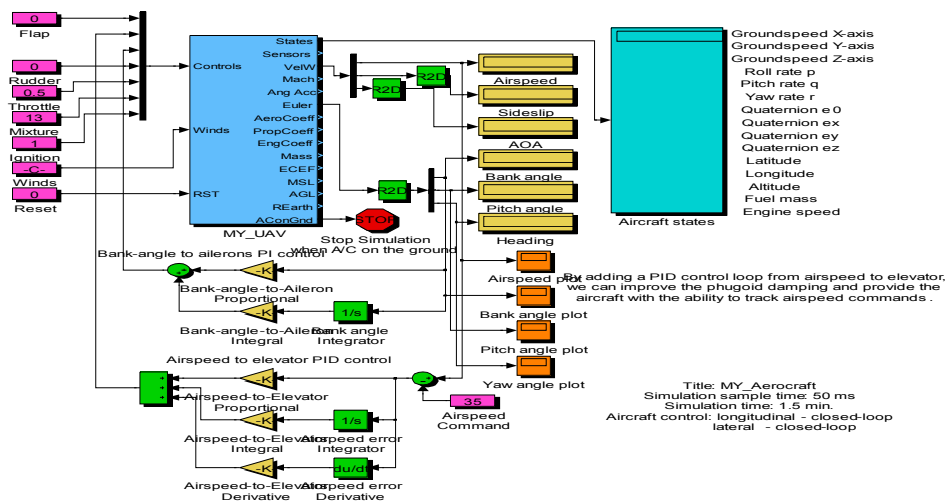


Figure 10. Structure Diagram of Aerocraft Model

Primary interrelated parameters is setting as follows:

1. The center of gravity for the aerocraft: $rAC=[0\ 0\ 0]$.
2. The aerodynamic parameters bound: airspeed bound $VaBnd=[30\ 80]m/s$, $\alpha =[-0.1\ 0.5]rad$, $\beta =[-0.5\ 0.5]rad$.
3. The structure parameters of aerocraft: $MAC=1.73736m$, $b=10.18m$, $S=17.5m^2$.
4. The installation position of the propeller: $rHub=[2.1875\ 0\ 0]m$, $Rprop=0.94m$, $Jprop=0.29264kg \cdot m^2$.
5. Empty load and full load parameter for takeoff: $mempty=1000kg$, $mgross=1274kg$, $CGempty = [0.156\ 0\ 0.079]m$, $CGgross = [0.159\ 0\ 0.090]m$. $Jempty = [0.7795\ 1.122\ 1.752\ 0.1211]kg \cdot m^2$, $Jgross = [0.8244\ 1.135\ 1.759\ 0.1204]kg \cdot m^2$.

Table 2. Initial Parameter Setting for Flight Simulation

tag (initial value)	parameters
Initial velocity	50m/s
Initial angle velocity	[0 0 0]
Initial altitude	1000m
Initial position	[pi/4 -0.677/pi 1000]
Initial fule mass	200kg
Initial engine speed	251rot/min
Initial altitude	20m
Sample time	50ms

The aircraft model framework for this flight simulation system and its initial parameter value is setting as Table 2.

The airspeed and pitch angle have add PID control loop, which could improve steady for the system. when Winds=[0 0 0] and Winds=[5 -3 0](namely in idea environment and in disturb environment), the typical parameter such as Airspeed, Bank angle, Pitch angle and Yaw angle of the aerocraft is shown as Figure 11(a)~11(d).

The initial airspeed is setup as 50m/s, and its steady value is 35m/s. we can see that the airspeed of aerocraft is gradual steady to 35m/s by 20s, the Figure 11(a) we can see that through about 20s the airspeed is steady to 35m/s. in the wind environment, it appear shake in 35m/s, which state is very like the real environment. From Figure 11(b) we can see that the Bank angle of aerocraft is steady to 0°from 0.8°by 20s, namely the flight state of aerocraft is turning to parallel flight state from slantwise flight state; from Figure 11(c) we can see that the Pitch angle of aerocraft is steady to 13°, namely the aerocraft is climbing; from Figure 11(d) we can see that the Yaw angle of aerocraft is steady to 0°(namely 360°) by 20s, namely the aerocraft is in straight flying state.

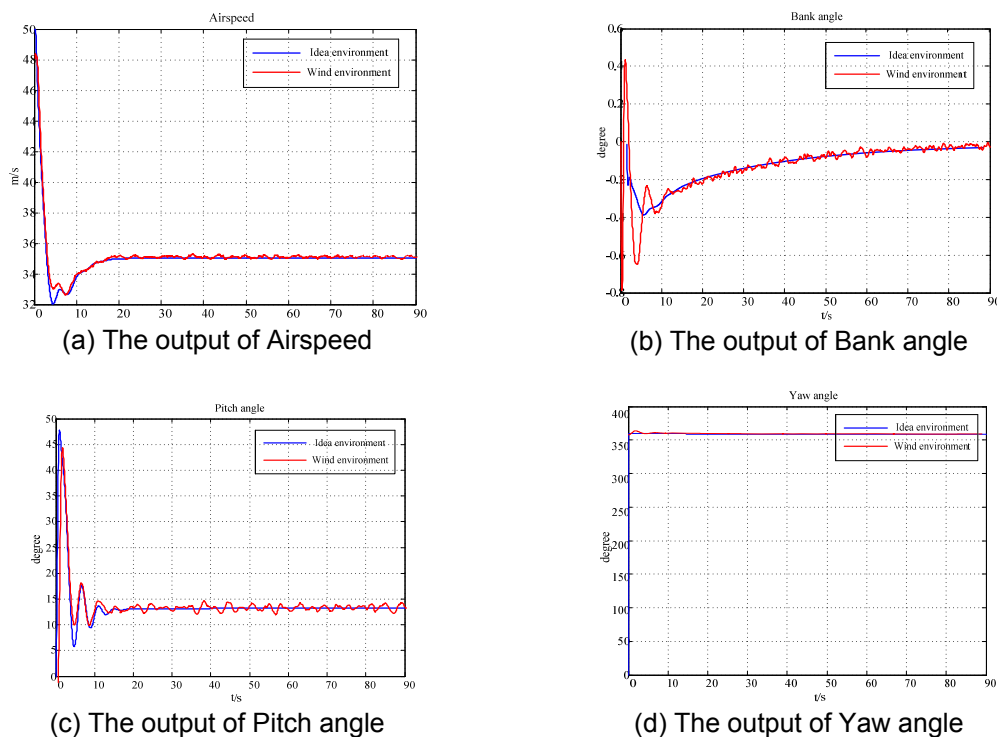


Figure 10. Output of the Parameters

5. Conclusion

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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