FLIGHT SIMULATOR DEVELOPMENT IN CHINA

Wang Xing Ren   Peng Xiao Yuan   Feng Qin

The Third Research Division,Dept. of Automatic Control,
Beijing University of Aeronautics and Astronautics,
100083,Beijing,P.R.China

Abstract

Recently,flight simulator is used widespread in pilot training and airplane design. Since 70's the flight simulators controlled by digital computer have been researched in China. Flight simulator consists of digital computer system and interface, 6-DOF motion system, digital control loading system, CGI visual system, flight compartment, modeling and software of simulated system.

This paper will discuss the key technology of above subsystem and our research experience.

I.Introduction

The flight simulation is one of the best method in design of aircraft and its airborne avionic system, and in training of pilot.
There are two kinds of flight simulation:
(1).Hardware-In-Loop(HIL) Simulation (Fig.1)
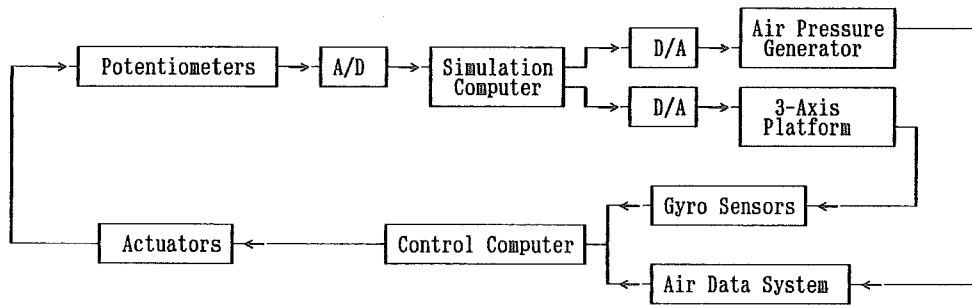(2).Man-In-Loop(MIL) Simulation (Fig.2)

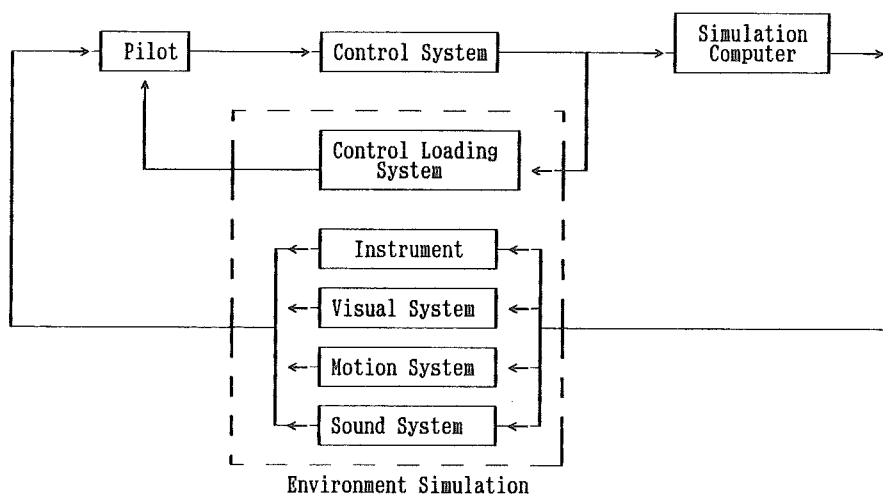Fig 1. Hardware-In-Loop Simulation

Fig 2. Man-In-Loop Simulation

The development of flight simulation in China can divide into two periods:

1.Before 70's

In early 50's,the dynamic simulation laboratory had been built in some university, research institute and factory. The Hardware-In-Loop Simulation played very important role in research and design of flight control system.HIL Simulation requires that some real aviation equipment or system(especially some sensors) insert in simulation close loop,so simulation equipment(3-axis platform,static/dynamic air pressure generator) is necessary.In this time,the analog computer and hybrid computer was used in simulation system.

2.After 70's

In this period,the HIL Simulation and MIL Simulation rapidly develop in China.All the simulation systems use digital computer.

The first flight simulator was began to design and manufacture in 1975.It has three-degree-of-freedom motion system,TV camera/Model board visual system and analog control loading system.Using this flight simulator can train the pilot.

Recently,Y7 commercial aircraft flight simulator is designed and manufactured(Fig 3). It takes a lot of advanced technology.It has six-degree-of-freedom motion system, Computer Generated Imagery(CGI) visual system,digital control loading system and touch activated screen instructor station.

Some R&D flight simulator was built in some research institute.

The functions of R&D flight simulator are:
1).Flight dynamics and handling quality research.
2).Research of aircraft controlability and stability.
3).Design of control law of flight control system.
4).Display and instrument configuration.
5).Evaluation of avionics system hardware and software.
6).Evaluation of weapon systems.
7).Tactics research.
8).Air combat.

II. Simulated System

The flight simulator has been designed to simulate the flight performance,engines performance,aircraft system performance, avionics system performance and environment characteristics to a high degree of fidelity. The simulated systems are:

Flight System--Calculates the aerodynamic coefficients,provides computation of the forces and moments acting on aircraft due to aerodynamics, propulsion,flight controls, and external environmental effects. The resulting translation and angular accelerations are computed and integrated to obtain aircraft attitude and position.

The mathematical model will include environmental conditions,the properties of atmosphere,the surface wind,wind shear profiles,turbulence,and icing effect.

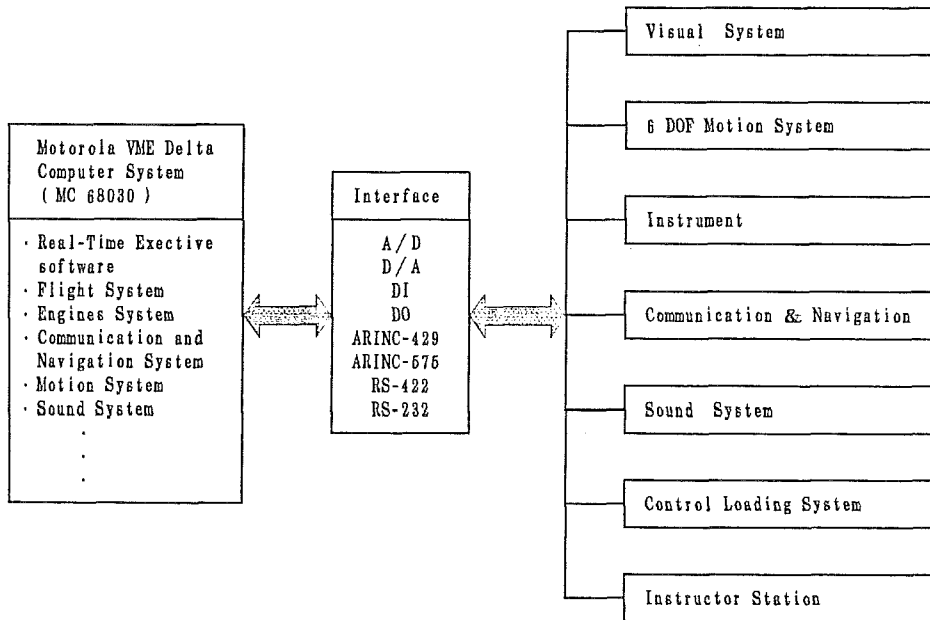| Motorola VME Delta Computer System (MC 68030)		Interface		Visual System
· Real-Time Exective software · Flight System · Engines System · Communication and Navigation System · Motion System · Sound System		A/D D/A DI DO ARINC-429 ARINC-575 RS-422 RS-232		6 DOF Motion System Instrument Communication & Navigation Sound System Control Loading System Instructor Station

Fig 3. Y7-100 Flight Simulator

The diagram of flight system modeling is shown as Fig4.

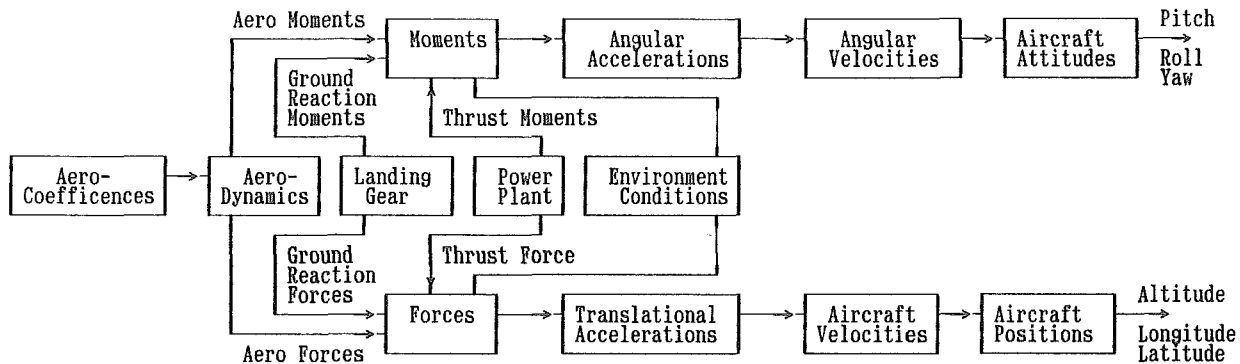first six-degree-of-freedom motion system was began to design and manufacture.

Fig 4. Modelling of Flight System

Power Plant System—Engine starting characteristics will be simulated.

The relationship between the simulated engine and power lever movement will be analogous to the aircraft engine.The relationship of the engine parameters, RPM, ITT,thrust torque,etc.,will be correctly computed for all atmospheric conditions.

Communication and Navigation System—The function of VHF communication system,UHF communication system,intercom system will be simulated.

The basic navigation problem of computing distance and bearing will be solved.VHF navigation module will provide the correct navigation indications associated with all types of VOR and ILS.The automatic direction finding(ADF) and markers will be simulated.

Flight Control System—The primary flight controls(columns,control wheels and pedals) will be loaded by electro-hydraulic servo system,using very low friction,hydrostatic force jacks.Digital modeling ensures realistic simulation of the aircraft primary control feel forces,including centering spring and breakout forces,aerodynamic forces, inertia, friction, position limits,etc.

Aircraft System—Includes fuel system, electrical system, hydraulic system etc.

The electrical system module will simulate the charge/discharge characteristics of batteries, the starter and the generator system, the circuit breakers effect, the cockpit controls and indicators.

The hydraulic system module will simulate the dynamic change of pressure while the operating of landing gear or flap extension and retraction.

Environment Simulation System—includes motion system,visual system,sound system,etc.

III.Motion System

In 1978,the first three-degree-of-freedom motion system was built in China. In 1985,the

The six-degree-of-freedom synergistic hydrostatic bearing motion system provides a hydraulically-driven, electronically controlled moving platform on which the cockpit,instructor station, visual display modules are mounted.

Motion system drive signal includes two parts: 1).primary drive signal.2).special effects signal.

The primary drive programs accept aircraft accelerations and velocities from flight system. Through the coordinate system transformation, washout and gravity alignment algorithms, the outputs of program are motion platform accelerations and velocities. For the roll axis,onset cues are provided but steady-state roll attitude is washed out and the platform is returned to its neutral position. For the pitch axis,steady-state pitch attitude is representative of that in aircraft. Gravity alignment is used to simulate sustained acceleration in the longitudinal and lateral axes.The motion platform accelerations are integrated and filtered to get motion platform positions. Then,the motion platform positions are transformed into actuator positions by the geometric transformation equations.

The special effects programs provide the fixed-frequency vibrations, random vibrations and discrete bumps.

The basic principle diagram of motion system is shown in Fig 5. The motion system performance is listed in table 1.

IV.Visual System

The CGI visual system provides a realistic out-of-window view to the pilot. The scene is generated by computer image generation equipment, which interface with the host computer, to receive aircraft attitude, altitude, and position data. The out-of-window scene accurately represents the changing perspective of the real world as the aircraft responds to pilot control movements. The scene which the pilot sees in simulated flight is determined by the data base chosen by the instructor station. Day/Night/Dusk
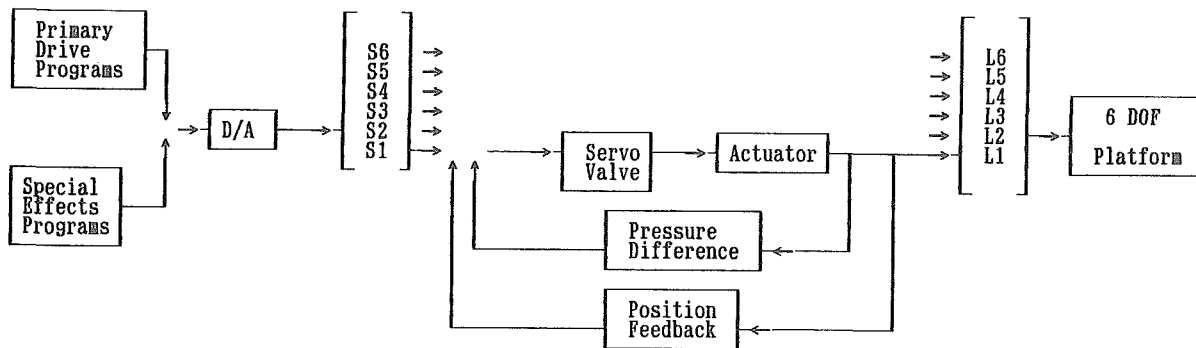
2106

Fig 5.　6 DOF Motion System

	Longitudinal X	Vertical Z	Lateral Y	Pitch θ	Roll Φ	Yaw ψ
Excursion	+0.815 m −0.72 m	1.28 m	± 0.815 m	+25° −27°	± 21°	± 33°
Velocity	± 0.65 m / s	± 0.65 m / s	± 0.65 m / s	± 23° / s	± 23° / s	± 23° / s
Acceleration	± 0.9 g	± 0.9 g	± 0.9 g	± 220° / s^2	± 220° / s^2	± 220° / s^2
Acceleration Onset	± 15 g / s	± 15 g / s	± 15 g / s	± 500° / s^3	± 500° / s^3	± 500° / s^3
Frequency Response	2.8 Hz (−3db) 3.4 Hz (−90°)					
Load	4000 Kg					

Tabel 1. Motion System Performance

conditions, weather effects and airport details offer effective training for operation of take-off and landing. Scene data bases are constructed using lightpoints and polygons. The image generated through real time solving of equations in multi-computer, presents a true perspective picture of a data base from any view point in space. The visual system performs the coordinate transformations, color intensity calculations, clipping and to fill the color of each pixel to frame buffer for display.

In 1985,the first CGI system was accomplished in China. For meeting advanced visual requirements, the new architecture visual system are applied in several simulators in 1989. Its specifications are shown as follows:
Mode: day/dusk/night.
Surface/Lightpoint:
　1000　surface/each channel.
　1600 lightpoint/each channel.

Field of View: 48°×36° (each channel).
Level of Occulting: 10.
Color: 256.
Resolution: 768×512.
Shade: Yes.
Update and Refresh Rate: 25 frames/sec.
Transport delay < 150 ms.
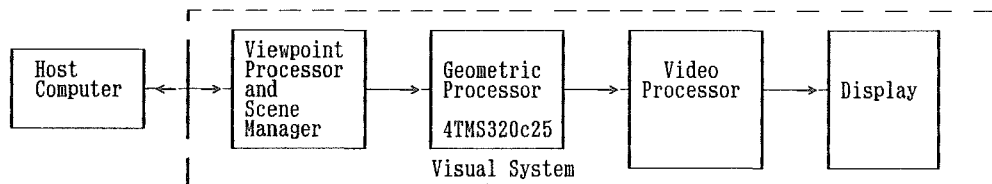Virtual image display: Yes.
Number of Channels: 3 to 4.

Fig 6. CGI System

Figure 6 shows a basic configuration of this CGI visual system in one channel. The system is structured as a pipeline of processing units where computing tasks are distributed along a sequence of dedicated computing elements. The system also structured as a parallel processor because of the greater computational requirement.

Today a CGI research projects are being developed by several institutes in China. The advanced CGI visual system are developed to provide the good performance for training that require a much wider field of view, higher resolution(Area-of-interest or AOI), higher fidelity and quality (texture, shadow, shading,translucency, anti-aliasing, level of detail, overload management and more weather effect etc.). The design philosophy in this modern CGI systems tends to emphasize modularity. With the rapid advance in VLSI technology, the new CGI systems use the VLSI and FPGA technology efficient design.

V. Key Technology

Flight simulator have been applied in engineering design of aircraft and training pilot. The key technology and its developing tendency will be described as following.

1.General Mathematical Models and Software Modules

Equation of six-degree-of-freedom motion is the same for all fixed-wing airplane.So we can build the general or standard mathematical models and software modules for equation of motion.We also can design the standard form of the model of wind shear and turbulence. Some real-time algorithm subroutines are common.

General mathematical models and software modules will reduce the work-load of modeling and programming of flight simulator.

2.Multi-Processor and Multi-Rate Distributed Computer System

Flight simulator is one kind of man-in-loop simulation,it must be simulated in real-time. The basic iterate rate may be 20HZ,30HZ,or 60HZ.Some subsystem's iterate rate is 500HZ,1000HZ or 3000HZ. How to solve the real-time simulation for complex system? the better way is to design multi-processor distributed computer system and multi-rate software modules/interface data communication.

3.Real-Time Graphic and Imagery Technology

The running status, flight trajectory, time-history of parameters, resulting output of flight simulator can be displayed on CRT screen in real-time by graph and image.

The touch activated CRT of instructor station may have more than 1000 pages.

The out-of-windows scene is produced by CGI system. The technological advances have made possible a greater level of detail of real world simulation and lower cost of visual system.

4.Simulation and Stimulation

Modern aircraft is equipped with digitized,integrated avionics system some real equipment of aircraft will be directly inserted in man-in-loop simulation system. These real airborne equipment don't require to simulation, but connect with main simulation computer by stimulation.

5.Flight Simulator Management System

Flight simulator consists of several subsystem. The flight simulator management system will provide the capability of preflight readiness checkout, automatic setting initial conditions, on-line monitoring and assessment of the simulator response, automatic or semi-automatic testing of flight simulator, edition of lesson plan, setting of malfunctions, lock and freeze, maintenance diagnosis, etc.

6.Application of AI Technology to Flight Simulation

Recently,the flight simulator failure diagnosis and maintenance expert system, the performance assessment expert system, the flying control expert system and the operational expert system are researched and developed.

7.Flight Simulator Network

There is a trend in flight simulation today toward to build flight simulator network,which consists of multiple participants, both manned and unmanned—the single flight simulators, low-cost pilot stations, and computer controlled aircraft. For example, the real-time air combat environment simulation system has multiple participants.

8.Simulation Software Configuration Management System

The simulation software will support the flight simulator including engineering research, training, the evaluation of system performance and student pilots, and equipment test and maintenance. The simulation software consists of real-time operational programs, simulator support programs, computer operating system and utility programs, maintenance and test programs. A configuration management system will control and manage the simulation software.

VI.Conclusion

Flight simulator has been applied widespread to engineering research and pilot training in China.

Flight simulator collects a lots of advanced technologies. In future, we are going to research and develop the above key technologies of flight simulator, and to design and manufacture new flight simulator for commercial and military aircraft.