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Design of 3d Display Control Comprehensive Training System for UAV

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Abstract. To meet the demand of the UAV flight control and maintenance personnel training simulation, this paper proposes the composition of 3d display control comprehensive training system of an unmanned aerial vehicle (UAV) and its working mode, this paper also expounds the module design of the system, implementation method and key technology. The disturbance plane motion model and the methods for generating three-dimensional visual are given. Practice shows that the three-dimensional simulation system has living effect and can be used for flight training, maintenance and operation training and self-study examination. This can save the cost of training and has a good prospect of application and popularization.

1 Introduction

The man-machine flight personnel cultivation mainly depends on the live-fire training flight, simulated flight time accounts for only 30% of the total training time[1]. But UAV control personnel training has the essential difference, a lot of training work is performed by the ground simulation training. Therefore, the ground simulation training system should meet the needs of training operators for unmanned aerial vehicle. Because the drone operators don't have actual air flight experience, they need to use 3d display system training its air situational awareness, accurate grasp of UAV in a three-dimensional space position and surrounding condition, emergency in response to the air, and the traditional three-dimensional display system is expensive and has limited service life, so it is difficult to meet the demand of training.Aiming at the defects of the traditional technology, a low-cost UAV of three-dimensional display control comprehensive training system is proposed, the display platform of the system is built by the active three-dimensional curved surface, realizing 3d video driver and stereo display driven by 3d interactive technology and three-dimensional technology, the high simulation of human-computer interaction is realized by interactive hardware. Establish a multi-sensory stimulation manipulation of the environment on the ground, which has three work modes including the flight control training, maintenance operation training, self-study examination. Through the system, the UAV operators can master the UAV control method, operation process and special disposal method, they can also get accurate perception of the plane condition and environment situation of the three dimensional space. Maintenance personnel can be quickly familiar with the principle of UAV, the structure and function, the method of security processes and maintenance. The system can be used for general middle and small UAV flight control simulation training and maintenance personnel, as well as can provide the technical support for the development of comprehensive training system. It can ease the problems of the live-fire quantity less, limited service life and the limited number of training, it has a very high value of application and popularization.

2 The composition and the working mode of the system

UAV 3d display control comprehensive training system is mainly used in flight control training, maintenance operation training and self-study examination.

2.1 The hardware composition of the system

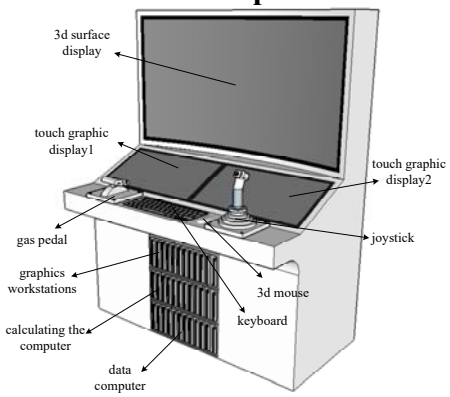

Figure 1 The system of hardware composition

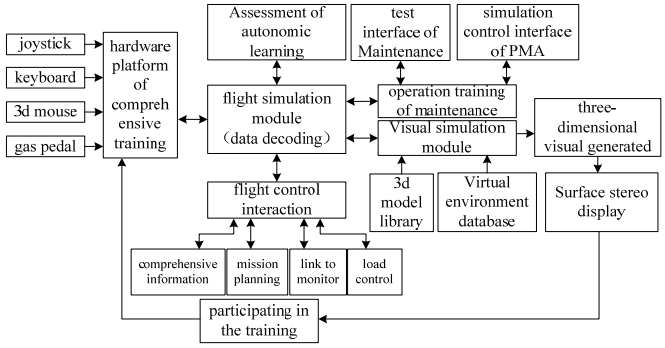

Figure 2 The structure of the system

The hardware structure of the system is shown in figure 1. The hardware of the system mainly consists of control system, display system and servers. Control system includs driving rod, throttle, keyboard, 3d mouse and touch screen, which is used to receive and transmit data to the computer. Display system is used to display the corresponding action and parameters.

2.2 The working mode of the system

The system is integrated three training modes, namely the flight controls training mode and maintenance training mode and autonomous learning evaluation model.

3 Implementation method of the system

The system includes five functional modules, such as the flight simulation module, visual simulation module, the flight control interactive module, maintenance operation training and self-study examination module, the structure of system is shown in figure 2.

4 The flight simulation module

The module uses the aircraft aerodynamic parameters to set up dynamic model of flight and control law, and the simulation uses the method of mathematical simulation aircraft pneumatic and power system, steering gear, flight control and navigation computer real devices, such as receiving control instruction, to produce the aircraft's flight, location information, flight parameters such as distance, which is the core of the whole training system.

4.1 Centroid dynamics model of the plane[2][3]

$$\begin{cases} F_x = m(\dot{u} + qw - rv) \\ F_y = m(\dot{v} + ru - pw) \\ F_z = m(\dot{w} + pv - qu) \end{cases} \tag{1}$$

The acceleration in the body of the shafting components as:

$$\begin{cases} \dot{u} = F_x / m - qw + rv \\ \dot{v} = F_y / m - ru + pw \\ \dot{w} = F_z / m - pv + qu \end{cases} \tag{2}$$

$\vec{F}$ represents force of aircraft force, $\vec{i}, \vec{j}, \vec{k}$ represent the unit vector in the body axis, F_x, F_y, F_z represent the force to the body axis of aircraft component, m represents the total mass of the plane, $\vec{V}$ represents the velocity vector of the plane, u, v, w are the components of flying speed in the body of shafting, $\vec{\omega}$ is the angular velocity vector of the plane, p, q, r are angular velocity in the body of shafting components for aircraft.

4.2 The kinematics model of plane centroid

Usually consists of three aircraft stance euler angle to determine (that is, the yaw Angle, pitching Angle and roll Angle), three euler angular velocity direction to the body axis direction projection are:

$$\left.\begin{aligned} p &= \dot{\varphi} - \dot{\psi}\sin\theta \\ q &= \dot{\theta}\cos\varphi + \dot{\psi}\cos\theta\sin\varphi \\ r &= -\dot{\theta}\sin\varphi + \dot{\psi}\cos\theta\cos\varphi \end{aligned}\right\} \tag{4}$$

We can obtain three euler angles：

$$\left.\begin{aligned} \psi &= \int((q\sin\varphi + r\cos\varphi)\sec\theta)dt \\ \theta &= \int(q\cos\varphi - r\sin\varphi)dt \\ \varphi &= \int(p + \dot{\psi}\sin\theta)dt \end{aligned}\right\} \tag{5}$$

4.3 The perturbation motion model of the plane

Calculate the true airspeed in the body axis component by type (2):

$$\left.\begin{aligned} u_A &= u - u_W - u_{RA} \\ v_A &= v - v_W - v_{RA} \\ w_A &= w - w_W - w_{RA} \end{aligned}\right\} \tag{6}$$

Set up the cosine matrix A of earth's axis is to the body axis direction

$$A = \begin{bmatrix} l_1 & l_2 & l_3 \\ m_1 & m_2 & m_3 \\ n_1 & n_2 & n_3 \end{bmatrix} \tag{7}$$

$l_1, \cdots, m_2, \cdots, n_3$ are the direction cosine, the velocity can be expressed as in ground coordinate system u_e, v_e, w_e:

$$\begin{bmatrix} u_e \\ v_e \\ w_e \end{bmatrix} = A^T \begin{bmatrix} u \\ v \\ w \end{bmatrix} \tag{8}$$

Conclud that the spatial location in the aircraft on the ground coordinate system as follows:

$$\left.\begin{aligned} X_g' &= \int u_e dt \\ Y_g' &= \int v_e dt \\ Z_g' &= \int w_e dt \end{aligned}\right\} \tag{9}$$

4.4 The simulation verification

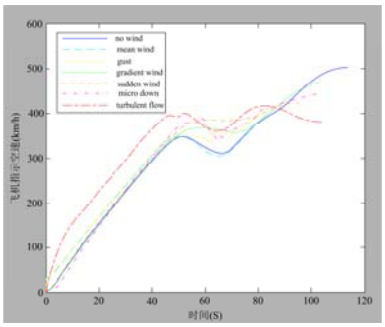

Figure 3 The plane indicated airspeed response under various disturbances

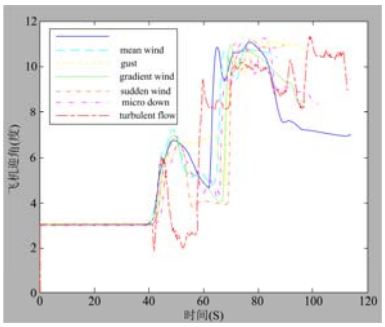

Figure 4 The plane angle of attack response under various disturbances

As shown in Figure 3 and Figure 4, you can see that the established model can realistically reflect the various wind field on the response of the flight performance of the UAV, to obtain satisfactory simulation results, which can satisfy the demand of the UAV flight training operators.

5 The visual simulation module

This paper presents a vector digital maps as constraints, combined with the surface texture generate three-dimensional landscape drawings, ensuring the authenticity and accuracy of the terrain database, solving the problem cannot be changed after the terrain library generation. Abstract model is:

$$S_1+S_2+\text{---}+S_n+T=R \tag{10}$$

S_1, S_2, S_n present different surface texture, and the T presents vector maps, R represents the generated three-dimensional landscape.

Specific process is:

1. Build and initialize the vertex data structure. Read the map file and constructe vertex arrays. Each vertex is made of two parts, which are three-dimensional coordinates and attributes.
2. Generate DEM data through the contour data. The contour data is imported into DEM analysis module of MAPGIS to get a regular grid DEM data.
3. Make interpolation to the unknown elevation point of DEM data.
4. Figure each vertex belongs to which primitive which is determined by the spatial relationship between vertices and vertex.
5. Iterate through all the vertices to assign the three-dimensional coordinate values.
6. Draw the terrain mesh according to the vertex coordinates.
7. Choose a suitable texture by comprehensive all vertices attributes.
8. Traverse the vertex, grid terrain texture mapping according to its attribute, and texture fusion in figure border.

6 The design of stereo display program

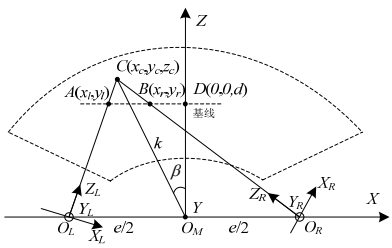

Figure 5 Type double center imaging model

This paper uses the funnel type double center imaging model as shown in Figure 5, the binocular fixation point C is limited in the dotted line box, around the center line of the 65 ° and the change of convergence angle is ±1.5°, which are according with the level of the human eye sight, to obtain a good visual effect.

The left camera $A(x_l, y_l, z_l)$ projection coordinates are as follows:

$$\left((x_c+\frac{e}{2})d/z_c, \frac{y_c d}{z_c}, d\right) \tag{11}$$

The right camera $B(x_r, y_r, z_r)$ projection coordinates are as follows:

$$\left((x_c-\frac{e}{2})d/z_c+\frac{c}{2}, \frac{y_c d}{z_c}, d\right) \tag{12}$$

d is the distance between the camera and XOY plane, e is the distance between the two viewpoints.

The relation model between the parallax i of visual $C(x_c, y_c, z_c)$ in the left and right eyes , the focal length f ,baseline distance h and light heart angle is as follows:

$$\frac{i}{f}=\frac{(4x_c-2h)k\cos\beta+z_c(2h-4k\sin\beta)}{4z_c k\cos\beta-h(2x_c-h)+2(2y_c-h+2x_c)d\sin\beta}-\frac{(4x_c+2h)k\cos\beta+z_c(2h+4k\sin\beta)}{4z_c k\cos\beta-h(2x_c+h)+2(2y_c-h-2x_c)d\sin\beta} \tag{13}$$

7 Summary

This paper presents method and key technology of 3d display control comprehensive training system for UAV. 3d image effect is distinct and immersive feeling, it can be used for general middle and small UAV flight control training and maintenance operation training to reduce risk and avoid unnecessary loss caused by error.

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