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The research of 6-DOF flight simulator washout filter Control Method

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***Abstract*：** Electric 6-DOF flight simulator used in large aircraft engineering simulation has great benefits，As a Flight Simulator vector parallel six degree of freedom motion system is a very important part of flight simulator. Feeling is the most important in Flight simulator test while flight.If a flight simulator can feel closer to the real feeling of flying aircraft, in is more better for trainning.According to the question above, In this paper, we will start from the control method,make research on electric 6-DOF flight simulator wash out the filter control method, we will research Longitudinal studies of flight parameters at takeoff position flight simulator. Using MATLAB simulation software to verify washout filter algorithm practicality simulator Simulation.
***Keywords*：** *Electric six degrees of freedom；Flight Simulator;Wash out the filter*

I. INTRODUCTION

Using flight simulator has many advantages such as: environmental protection, safety, save money and so on. Six degrees of freedom motion system is a core part of the flight simulator. It can be on the ground to provide dynamic flying directly to pilots. The performance of sport system is directly related to the fidelity of flight. So it is very significant to increase the performance of motion systems.Motion control algorithm in the system to provide pilots should also be considered dynamic electric cylinder stroke limitation. In order to avoid a false sense of control algorithm should be introduced to wash out the movement, so that after the end of the first movement with a minimum return to the origin of the next acceleration of simulation. In this paper, MATLAB software simulation results show that the algorithm has better fidelity.

ⅡThe introduction of 6 - DOF Parallel Platform

Six degrees of freedom parallel platform mechanism with the series compared with therational layout, stiffness, etc.it is widely used in flight simulators, structure diagram shown in Figure I. Six degrees of freedom motion platform,the most important question is to analyze the relationship between the input and output between solving mechanism onstructed.The proposed algorithm only involves inverse solution platform.

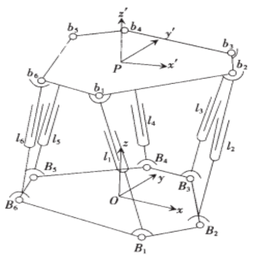


Figure Ⅰ：six degrees of freedom motion platform of mechanism

2.1、Determining Dimensions of Platform

The up platform outer radius R, the lower platform outer radius R0, the platform adjacent to the base angle β0, under two adjacent base angle β platform, the platform each hinge point in the coordinate system Px'y'z 'in coordinate values (bi), under the platform of each hinge point (Bi) coordinate values in the coordinate system of Oxzy. Specific reference to Figures I and II and III(i=1,2…6):

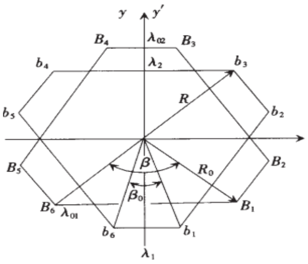
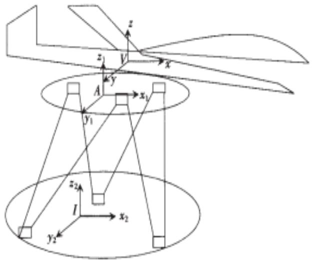


Figure Ⅱ: Platform plot

Figure Ⅲ: Figure simulator entity



FigureⅣ: Coordinate system Figure

2.2 Direction cosine matrix of the up platform

$\sigma_{1,}\sigma_{2,}\sigma_{3,}$ are three angles with respect to the moving platform platform

$$D=\begin{pmatrix} \cos\sigma_3\cdot\cos\sigma_2 & \cos\sigma_3\cdot\sin\sigma_2\cdot\sin\sigma_1+\sin\sigma_3\cdot\cos\sigma_1 & \cos\sigma_3\cdot\sin\sigma_2\cdot\cos\sigma_1+\sin\sigma_3\cdot\sin\sigma_1 \\ \sin\sigma_3\cdot\sin\sigma_2 & \sin\sigma_3\cdot\sin\sigma_2\cdot\sin\sigma_1+\cos\sigma_3\cdot\cos\sigma_1 & \sin\sigma_3\cdot\sin\sigma_2\cdot\cos\sigma_1+\cos\sigma_3\cdot\sin\sigma_1 \\ -\sin\sigma_2 & \cos\sigma_2\cdot\sin\sigma_1 & \cos\sigma_2\cdot\cos\sigma_1 \end{pmatrix}$$

2.3 Elongation of electric cylinders

$$S_{kx}=\cos\sigma_3\cdot\cos\sigma_2\cdot b_{kx}+x'-B_{kx}$$

$$S_{ky}=\sin\sigma_3\cdot\sin\sigma_2\cdot b_{kx}+\sin\sigma_3\cdot\sin\sigma_2\cdot\sin\sigma_1+\cos\sigma_3\cdot\cos\sigma_1\cdot b_{ky}+y'-B_{ky}$$

$$S_{kz}=-\sin\sigma_2\cdot b_{kx}+\cos\sigma_2\cdot\sin\sigma_1\cdot b_{ky}+z'$$

$$S_k=\sqrt{S_{kx}{}^2+S_{ky}{}^2+S_{kz}{}^2}-S$$

k=1,2…6, x',y',z' are coordinates of the point P of the up platform

II. THE ALGORITHM OF MOTION CONTROL

3.1The transformation Of Centroid

In order to facilitate the calculation and analysis we mark I coordinate is a coordinate system platform, the platform coordinates is, A simulator coordinates Referring specifically to Figure IV V. Aircraft centroid acceleration transform A coordinate system to:

$$a_{AV}=a_V+(\Omega_V\Omega_V+M_V)H_{AV}$$

$$a_{AA}=L_{AV}a_{AV}$$

$$\omega_{AA}=L_{AV}\omega_V$$

V_{xt},V_{yt},V_{zt} are the centroid point of absolute speed projected on the coordinate system, a_{xt},a_{yt},a_{zt} V is the centroid point in the coordinate system of the absolute acceleration of projection, p_v,q_v,r_v V is the centroid point of absolute angular velocity in projected coordinate system has

$\omega_v=\left[p_vq_vr_v\right]^T=\left[\omega_{xt}\omega_{yt}\omega_{zt}\right]^T$ Because the A and V two coordinate systems parallel to each other so drawn：

$$L_{AV}=\begin{pmatrix}1&0&0\\0&1&0\\0&0&1\end{pmatrix}\qquad a_V=\begin{pmatrix}a_{xt}+q_V\cdot\omega_{\overline{V}}-r_V\cdot V_y\\ a_{yt}+r_V\cdot v_{\overline{xt}}-p\cdot\omega_V\\ a_{zt}+p_V\cdot v_{\overline{yt}}-q_V\cdot v\end{pmatrix}\qquad \Omega_V=\begin{pmatrix}1&-r_V&q_V\\ r_V&0&-p_V\\ -p_V&r_V&0\end{pmatrix}$$

while simulation is running the pilot use the force to get feeling, $t = m - g$, and t is force ,m is Inertial acceleration,g is Acceleration of gravity.

$$L_{IA} = \begin{pmatrix} \cos\theta\cos\psi & \sin\psi\sin\theta\cos\psi - \cos\psi\sin\psi & \cos\varphi\sin\theta\cos\psi + \sin\varphi\sin\psi \\ \cos\theta\sin\psi & \sin\varphi\sin\theta\sin\psi + \cos\varphi\cos\psi & \cos\varphi\sin\theta\sin\psi - \sin\varphi\sin\psi \\ -\sin\theta & \sin\varphi\cos\theta & \cos\varphi\cos\theta \end{pmatrix}$$

$[\varphi\ \psi\ \theta]^T$ is euler angles while $Ax_1y_1z_1$ respect to $Ix_2y_2z_2$.

In this article we consider the simulation of aircraft longitudinal movement $\omega_{xt} = 0, \omega_{yt} = \frac{d\theta}{dt}, V_z = 0, \beta = 0$, β is sideslip angle, γ is roll angle, ψ is yaw angle。

$$\begin{cases} a_{xt} = \frac{dV_{xt}}{dt} - V_{yz}\frac{d\theta}{dt} \\ a_{yt} = \frac{dV_{vt}}{dt} + V_{xt}\frac{d\theta}{dt} - \frac{d\theta}{dt} \\ a_{zt} = 0 \end{cases} \qquad a_v = \begin{pmatrix} a_{xt} - V_{yt}\frac{d\theta}{dt} \\ a_{yt} + V_{xt}\frac{d\theta}{dt} \\ a_{zt} \end{pmatrix} \qquad H_{AV} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

x,y,z are according to the actual circumstances.

$$\Omega_V = \begin{pmatrix} 0 & -\frac{d\theta}{dt} & 0 \\ \frac{d\theta}{dt} & 0 & 0 \\ 0 & \frac{d\theta}{dt} & 0 \end{pmatrix} \qquad M_V = \begin{pmatrix} 0 & \frac{d^2\theta}{dt^2} & 0 \\ \frac{d^2\theta}{dt^2} & 0 & 0 \\ 0 & \frac{d^2\theta}{dt^2} & 0 \end{pmatrix}$$

$$a_{AA} = a_{AV}; \omega_{AA} = \omega_V = \left[\omega_{xt}\omega_{yt}\omega_{zt}\right]^T = \left[00\frac{d\theta}{dt}\right]^T$$

3.2 Motion control algorithm

Second-order high-pass filter transfer function

$$H(R) = R^2 / (R^2 + 2.04R + 1.0404)$$

Second-order low-pass filter transfer function

$$H(R) = 1.0404 / (R^2 + 2.04R + 1.0404)$$

Third-order high-pass filter transfer function

$$H(R) = (R^2 / (R^2 + 8.68R + 9.61))\cdot(R / (R + 0.2))$$

$$T_S = \begin{pmatrix} 1 & \sin\varphi\tan\theta & \cos\varphi\tan\theta \\ 0 & \cos\varphi & -\sin\varphi \\ 0 & \sin\varphi\sec\theta & \cos\varphi\sec\theta \end{pmatrix}$$

Z Represent the following:

$$Z = \begin{cases} \varphi_1 = \arctan(f_{Ly} / f_{Lx}) \\ \theta_1 = \arctan\{(f_{Ly} / f_{Lx})\cos\phi_L\} \\ \psi_1 = 0 \end{cases}$$

III. MAKE SIMULATION

Based on the above analysis and calculations, we draw a block diagram of the control algorithm as follows:

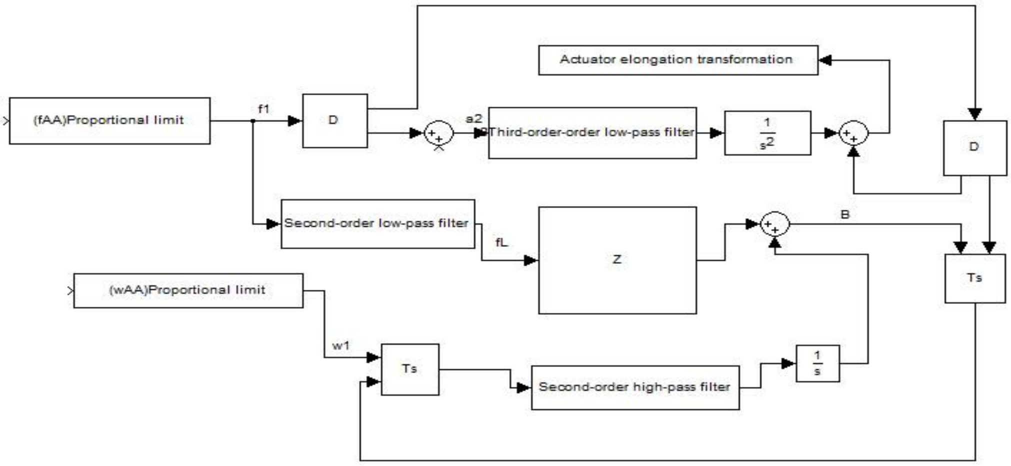
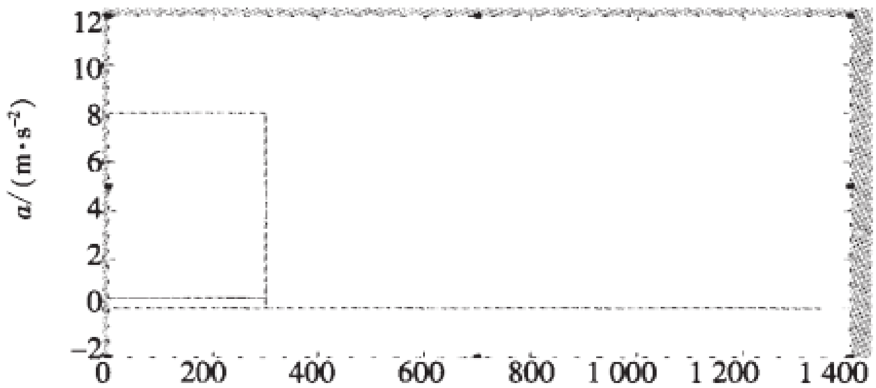
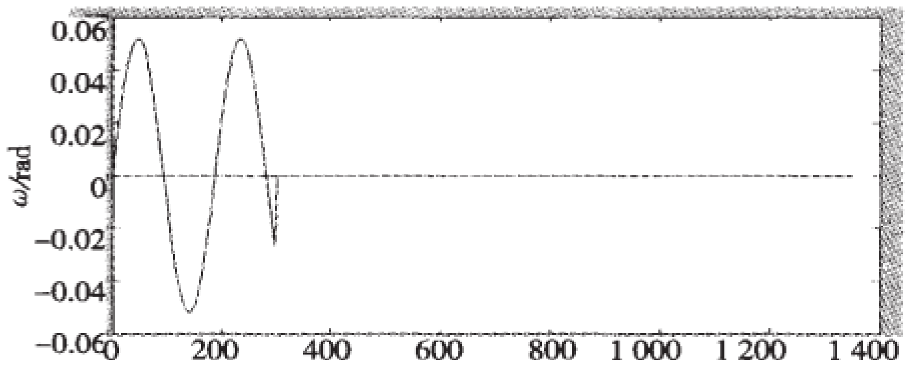


Figure Ⅴ: the schematic diagram of the control algorithm

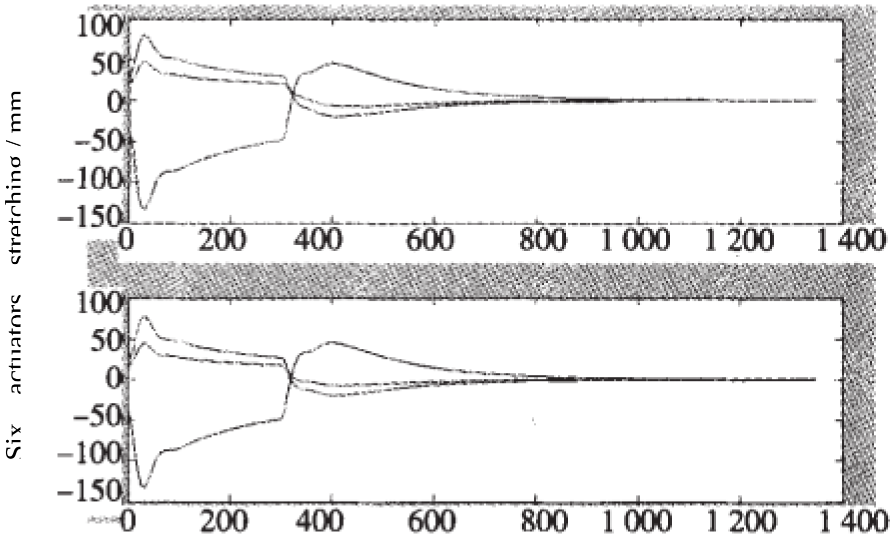
Make simulation analysis ,Figure VI a and b figure is input simulation analysis, c chart is in a, b of the input of the six actuators amount of stretching：



Sampling points (a)



Sampling points （b）



Sampling points (c)

Figure VI: Data Simulation

IV. CONCLUSION

According to various analysis and calculation， we found six actuators in complete simulated flight at the same time it has a very reasonable amount of stretching。It is not only make flight success in the case of theexisting length of the flight,but also it has a good effect to wash out . we can conclude that the washout filter Control Method can be used to develop the 6-DOF flight simulator system at last.

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